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Design and Modelling of an Automated Strap: On Precision Syringe Injector Device

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Abstract: *The project focused on designing and modeling a self-injecting device using locally sourced materials and tools, aiming to enhance accuracy, speed, and cost-efficiency in medical applications. The design process involved CAD modeling, electrical and mechanical design, and rigorous testing, including buckling analysis and finite element analysis (FEA) using ANSYS to ensure the needle's effectiveness in penetrating skin with minimal buckling. The device's force requirement to push the syringe plunger was measured at 39.8N, with the stepper motors exerting a torque of 0.3Nm. After integrating the electrical and mechanical components, the prototype was successfully tested on a dummy human, demonstrating its capability to perform precise self-injections with the press of a button, confirming its operational effectiveness.*

Keywords: Self-injecting device, CAD modeling, buckling analysis, finite element analysis (FEA), prototype testing.

INTRODUCTION

According to the encyclopedias almanacs transcripts and maps (2021), Syringes and needles are sterile devices used to inject solutions into or withdraw secretions from the body. A syringe is a calibrated glass or plastic cylinder with a plunger at one and an opening that attaches to a needle. The needle is a hollow metal tube with a pointed tip. This has been back dated to 9th

century: The Iraqi/Egyptian surgeon Ammar ibn 'Ali al-Mawsili' created a syringe in the 9th century using a hollow glass tube, and suction to remove cataracts from patients' eyes, a practice that remained in use until at least the 13th century and up till date numerous inventions and modifications have been done and carried out on the syringe and needle combo. (New Penguin Dictionary, 2011).

Since the innovation of needles and needles have been utilized for such countless purposes like; oversee drugs when a limited quantity of liquid is to be infused; when an individual can't take the medication by mouth; or when the medication would be obliterated by stomach related emissions and pull-out different kinds of body liquids, most generally tissue liquid from enlarged joints or blood from veins. These two fundamental motivations behind needle and needle use in these current occasions(Grabowska et al., 2010).

The infusion of liquids into the human body is conceivable with the utilization of an apportioning clinical instrument casually called a needle. The item comprises of a slim walled body as a tube-shaped holder and an exceptionally safe profile working as a cylinder. Since the two components can be made of polymer materials, the hot item will commonly fulfil specialized prerequisites and guaranteeing low assembling costs, bio non-partisanship and sterility. Results of this kind are acquired in a cyclic infusion process, which is the most generally utilized strategy for polymer plastics handling (Harper et al., 2006).

Durek and Pawela et al., (2008) affirmed that Creation expenses of a normal needle are low, as these days, multi-mass and large-scale manufacturing are broad. Thusly, engineers should design the innovative cycle and select the fitting boundaries in order to limit pointless capital uses, which incorporate the buy expenses of the gadget, devices, and material. Significant expenses of keeping up with the high-sterility workplace where clinical adornments and instruments are delivered additionally should be thought about. Consequently, do primer tests and near examinations in regard to the innovative cycle systems and the properties of the items to limit all expenses and objective determination of interaction conditions.

The Joint Commission Public Patient Well-being Objectives (2000), affirmed that Patient security in needle methods incorporate upkeep of a clean field utilizing dispensable clinical supplies if conceivable, rejection of patient medication sensitivities, cautious thoughtfulness regarding sedation conventions, acknowledgement and amendment of coagulation status, right tolerant/usable site affirmation, pre-cut cross examination of the objective with the imaging methodology to characterize usable life structures, post-technique perception and care, impulsive naming, authority, and handling of the biopsy test, cautious needle control during and after the strategy, and brief acknowledgement of entanglements. In the present randomized-controlled review preliminary, we contrasted a customary needle with a mechanical system needle and inspected the impact of needle size on goal methods including hand power needed to suction, biopsy yield, vacuum age abilities, and control of the needle tip, all which have direct importance to patient security.

Durek & Pawela et al, (2008) confirmed that Patient well-being in needle methods incorporate upkeep of a clean field utilizing dispensable clinical supplies if conceivable, rejection of patient medication sensitivities, cautious thoughtfulness regarding sedation conventions, acknowledgement and amendment of coagulation status, right tolerant/usable site affirmation, pre-cut cross examination of the objective with the imaging methodology to characterize usable life structures, post-technique perception and care, impulsive naming, authority, and handling of the biopsy test, cautious needle control during and after the strategy, and brief acknowledgement of entanglements.

Medical care teachers ought to guarantee that staff individuals are gifted in state-of-the-art strategies for aseptic strategy just as the right dealing with and utilization of needles and needles. All people directing infusions ought to know about current techniques for disease anticipation. Showing the right utilization of needles and needles, just as their removal, is essential to ensure clinical staff and individuals getting infusions from needle-stick wounds and defilement from blood-borne diseases. Starting at 2003, a portion of the more genuine contaminations are human immunodeficiency infection (HIV), hepatitis B (HBV), and hepatitis C (HCV).

The decision of needle size ought to be founded on the known impacts of needle size on the strength of vacuum age, the power needed to produce a particular degree of vacuum, the trouble to create vacuum, the volume of liquid to be suctioned or the necessary biopsy yield, needle control, and patient security contemplations. Even though, biopsy or liquid yield is significant, patient well-being and the known complexities of needle goal should be thought of, including discharge, hematoma, pneumothorax, and respiratory capture. The Joint Commission, the Needles-tick Security and Anticipation Act, the Word related Well-being and Well-being Organization (OSHA), the Patient Security and Quality Improvement Demonstration of 2005, and Veterans Organization Public Place for Patient Well-being and important public and global associations worried about well-being all urge doctors to amplify patient security during intrusive strategies, including mix of well-being advancements Needles-tick Safety and Prevention Act. US Congress (2006)

The evolution of syringe and needle technology has been driven by the need for precision, safety, and cost-effectiveness. Modern syringes are often made from advanced polymers, which provide advantages over traditional materials in terms of safety, sterility, and manufacturing efficiency. Innovations in design, such as retractable needles and pre-filled syringes, aim to reduce the risk of needlestick injuries and contamination. These advancements reflect ongoing efforts to improve healthcare outcomes by addressing issues related to the safety and efficacy of injection devices. Despite these developments, self-administration of injections poses risks, including improper technique and device misuse. Addressing these issues requires continued innovation and refinement in device design.

Self-administration of injections is increasingly common, driven by the need for chronic disease management and convenience. However, this practice is fraught with challenges, including difficulties in maintaining sterile conditions and the risk of needle-related injuries.

Studies have shown that improper injection techniques can lead to complications such as infections and tissue damage. The growing prevalence of self-administration emphasizes the need for devices that enhance ease of use and ensure accurate drug delivery. This has led to an increased focus on developing user-friendly devices that can mitigate risks associated with self-injection. Effective solutions must address both the technical and practical aspects of syringe and needle use.

The need for improved injection devices is underscored by safety concerns associated with traditional syringes and needles. For instance, issues such as needle breakage and incorrect injection angles can result in significant complications. These problems are exacerbated in settings where users lack adequate training or supervision. The consequences of these issues can range from minor injuries to serious infections or diseases. Addressing these safety concerns is crucial for improving patient outcomes and minimizing risks associated with injection procedures. Thus, there is a pressing need for innovative solutions that address these challenges effectively.

In response to these challenges, this project focuses on the development of an automated strap-on precision syringe injector. The goal is to design a device that facilitates safe and accurate self-administration of injections. By incorporating features that enhance ease of use and precision, the device aims to reduce the incidence of complications associated with traditional syringes and needles. The project also emphasizes the use of locally sourced materials for initial prototyping, aligning with the objective of creating a cost-effective and practical solution. Through this innovation, the project seeks to contribute to advancements in medical device technology. Ultimately, the aim is to improve patient safety and the efficacy of self-medication practices.

The design process for the automated precision syringe injector involves addressing several key factors, including device usability, safety features, and manufacturing feasibility. The device is engineered to incorporate advanced mechanisms that ensure precise drug delivery while minimizing user errors. A significant focus is placed on integrating features that enhance sterility and reduce the risk of contamination. Additionally, the project aims to develop a device that is compatible with various types of medications and injection sites. Rigorous testing and validation processes are integral to ensuring that the final product meets high standards of safety and performance. The goal is to deliver a device that offers reliable and effective solutions for self-injection needs.

The successful completion of this project has the potential to significantly impact the field of medical device technology. By addressing current limitations and safety concerns associated with syringes and needles, the automated strap-on precision syringe injector represents a meaningful advancement. The device's innovative features are designed to enhance patient safety and improve the overall experience of self-administration. Through its development and implementation, this project aims to contribute to better healthcare outcomes and the advancement of medical technology. Future work will focus on refining the design and

exploring broader applications to maximize the device's benefits. The project stands as a testament to ongoing efforts to improve medical devices and address the evolving needs of patients and healthcare providers.

METHODOLOGY

Design and modelling of an automated strap-on precision syringe injector device

The design and construction of the automated strap-on precision syringe injector device were carried out through a structured, multi-phase approach. Initially, the electronic components of the device were developed, followed by the programming of the robotic systems and the design of the mechanical elements. Although these stages often overlapped, each phase was crucial to the project's success. The design process began with the acquisition of software applications such as SolidWorks for 3D modelling and ANSYS for analysing the needle's buckling behavior. Subsequently, material selection was undertaken, accompanied by detailed specifications and preparation for the production process. The device was constructed cost-effectively using various construction algorithms within our local context. This section details the construction process, including the design of the device, component specifications, formulas, diagrams, and the fabrication of the circuit board. The results of the design are presented in tabulated format, showcasing the device's performance and construction efficacy.

Working Principle of Automated Strap-On Precision Syringe Injector

The gadget will be fuelled by a 11v power source which will give capacity to the entire framework. The two engines down will be invigorated and begin turning. The engines which are now connected to fastener and nut system, as the engine pivots it moves the downwards which thus conveys the instrument that holds the needle. When that cycle is done, there is additionally another screw and nut framework what begins following the main activity stops, this activity pulls the unclogged of the needle downwards to manage the medication, after which all components will get back to their rest positions.

Determination of Theoretical Buckling Load

Clasping hypothesis is administered by equation 1, the differential condition relating the inner snapshot of a section to its avoided shape.

$$EI = \frac{d^2v}{dx^2} = M \quad \ldots\ldots (1)$$

In equation 1, E is the material's versatile modulus, I am the snapshot of dormancy, v is the avoidance, x is the hub distance along the section, and M is the inside second. Subbing $= -Pv$, where P is the applied burden and addressing the subsequent differential condition for the basic burden, P_{cr}, yields equation 2:

$$P_{cr} = \frac{\pi^2 EI}{(KL)^2} = M \quad \ldots\ldots (2)$$

where L is the length of the section and K is a successful length figure that takes account the end states of the segment and scales the condition in like manner. This is the Euler load, which is substantial for long sections.

To decide if this condition is exact for this issue, it is important to check that the needles utilized in this examination can be addressed as long sections. This requires the utilization of the needle's thinness proportion, characterized as KL/r , where r, the span of gyration, is equivalent to $\sqrt{I/A}$, where and is the cross-sectional space of the needle. The basic length, L_{cr}, decides the legitimacy of the Euler clasping load, and is characterized in equation 3 as:

$L_{cr} = r\pi\sqrt{\frac{8E}{\sigma_y}}$, ... (3)

where σ_y is the compressive yield strength of the material. Accepting that the compressive yield strength is indistinguishable from the malleable yield strength, the basic length, taken for a normal breadth of 0.96 mm, is 28.3 mm. As this is more limited than the needle length of 38.1 mm, the Euler clasping equation can be utilized to assess the clasping attributes of the needles. For the 25.4 mm length needles, the normal breadth is 0.88 mm, and the basic length becomes 26.0 mm. As this figure is near the genuine length of the needles, both the Euler recipe and the Johnson equation for moderate length sections are used to decide the hypothetical clasping load.

$\frac{P_{cr}}{A} = \sigma_y - b\left(\frac{L}{r}\right)^2$ .... (4)

$b = \frac{1}{4E}\left(\frac{\sigma_y}{2\pi}\right)^2$ .... (5)

Utilizing the Euler clasping equation, the basic burden is roughly 6.1 N for the 38.1 mm length needles and 9.7 N for the 25.4 mm length needles. At the point when the Johnson equation is applied to the 25.4 mm needles, the subsequent clasping load becomes 19.0N. These outcomes are gauges due to the unpredictable state of the needles, the inaccurate course and area of stacking at the needle tip, and the gauge of the end conditions on the cannula. Nonetheless, they do give assessments of the needles' clasping loads, and these outcomes can be checked by both limited component investigation and trial testing. (Mark et al., 2002)

BENDING PRIOR TO PENETRATION

When examining sheet metal bowing, note the plastic (instead of versatile) disfigurement in the part, which is a controlled disappointment of the part. This is additionally applicable to the twisting of the polyurethane preceding infiltration, as deformity happens as the needle enters the polyurethane. Until entrance, the disfigurement is simply versatile. Disappointment is guaranteed when the tractable strain in the sheet is more prominent than the versatile strain. The elastic strain in the sheet made by twisting, ε_t, as shown in equation 6.

$\varepsilon_t = \frac{\Delta\ell}{\ell} = \frac{OA\prime - OA}{OA}$ .... (6)

By applying the substitution= $\frac{\Delta\ell}{\ell}$, the tensile strain becomes Equation 7.

$$\varepsilon_t = \frac{(r_p+t).\theta-(r_p+t/2).\theta}{(r_p+t/2).\theta} \quad \text{..... (7)}$$

where r_p is the punch range, θ is the point made by the bowing, and t is the thickness of the sheet.

$$\varepsilon_t = \frac{t/2}{r_p+t/2} \quad \text{..... (8)}$$

Stretching before Penetration

The polyurethane and skin likewise experience extending before needle entrance. This is a clear tractable stretch, with a pressure of $\sigma = FA$, where F is the applied 26 power and A is the cross-sectional region, and, from Hooke's Law, a strain, ε. As shown in equation 9 below.

$$\epsilon = \frac{FA}{E} \quad \text{.....(9)}$$

Joining these two pieces of the strain yields equation 10, the general strain following up on the polyurethane preceding real infiltration happening.

$$\epsilon = \frac{t/2}{r_p+t/2} + \frac{FA}{E} \quad \text{.....(10)}$$

To quantify the deformity preceding entrance, this strain should rise to the versatile strain in the polyurethane,

$$\epsilon = \frac{t/2}{r_p+t/2} + \frac{FA}{E} \quad \text{.....(10)}$$

In this manner, the strain condition that portrays the bringing down of the needle into the polyurethane before infiltration.

$$\frac{\sigma_{yield}}{E} = \frac{t/2}{r_p+t/2} + \frac{FA}{E} \quad \text{.....(12)}$$

The external skin layer is the just one remembered for these computations. It is harder than different layers, and the polyurethane skin mirror, into which the needles are being infiltrated during the analyses, just recreates the epidermis layer. The subsurface layers are in this manner disregarded for these computations.

Electrical Design

MATERIALS AND METHOD

In this project, attention is focused on research design and the stages/steps involved in the construction of this work. The materials needed for the design and construction of this project are given below:

1. Arduino Uno Programmer
2. Micro-controller (Atmega328p)
3. Crystal Oscillator
4. ULN2003 Stepper motor driver
5. Unipolar stepper motor
6. Resistor
7. Capacitors

8. Voltage regulators
9. Jumper cables etc.

Materials

i. Arduino Uno Board

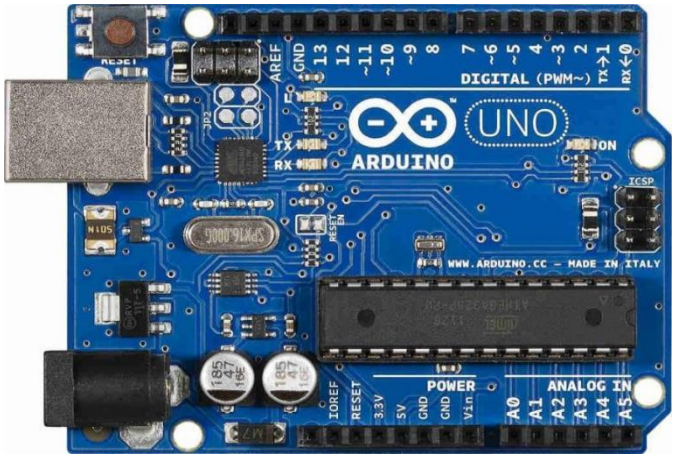


Fig 2.1: Arduino Uno R3 (source: wikipedia.com)

ii. Atmega328p Micro-controller

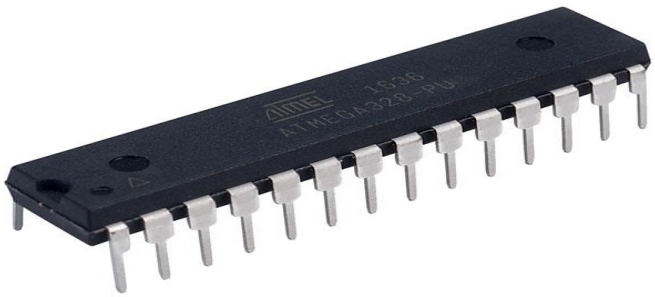


Fig 2.2 ATmega328P Miniature regulator (source: wikipidia.com)

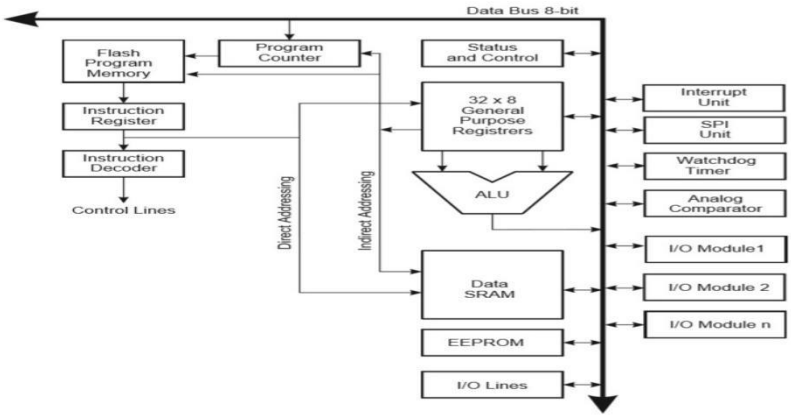


Fig 2.3: ATmega328 Miniature regulator Engineering (source: wikipedia.com)

iii. Crystal Oscillator

Fig 2.4 Gem Oscillator (source: wikipedia.com)

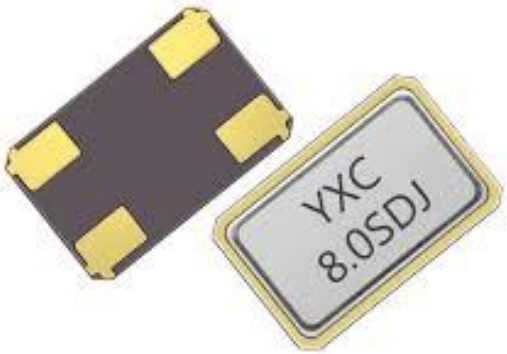


Fig 2.5 Quartz Precious stone Oscillator (source: wikipedia.com)

iv. Unipolar Stepper Motor

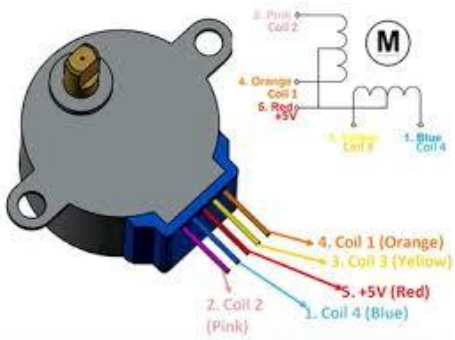


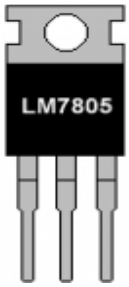
Fig 2.6 : Unipolar Stepper Motor (source: wikipedia.com)

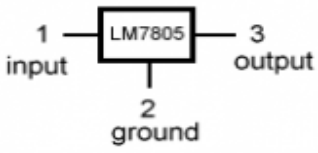
v. Uln 2003 Motor Driver

Fig 2.7: Uln2003 Engine Driver With Stepper Engine And Arduino (source: wikipedia.com)

i**v. Voltage Regulator**

Fig 2.8 (a) LM7805Physical appearance (b)LM7805Circuit outline





(source: wikipedia.com)

Description of Operation

When there is a quick stock of d.c power (5vdc) in the entire framework, the miniature regulator (atmega328p) which is the cerebrum of the entire framework conveys a yield signal through it yield pins (#2,3,4 and 5). The yields signal is gotten by the stepper engine driver module (DM1), the driver module gives out a comparing yield signal through it yield terminals to the stepper engines (m1 and m2) associated with it. At the point when the stepper engine is empowered, the engines (m1 and m2) move at the same time at a clockwise heading for 10secs all things

considered. Based on the mechanical compartment of the framework, during the principal turn process a fastener is mounted inflexibly to the engine, it s fixed that during its pivot the fastener will be in a bad way to a nut and still up in the air time (10secs) the miniature regulator seizes to supply sign to the before referenced pins at the termination of our customized time.

Besides, the miniature regulator gives one more arrangement of yield signal through it yield pin (6,7,8 and 9) to the subsequent stepper engine driver (DM2), which thusly stimulates the stepper engine (m3). The mechanical compartment for this engine is outfitted at controlling the splunger of our needle which should get a necessary tension (power) in other for the liquid to leave the spout.

Given beneath is the electrical circuit outline associations:

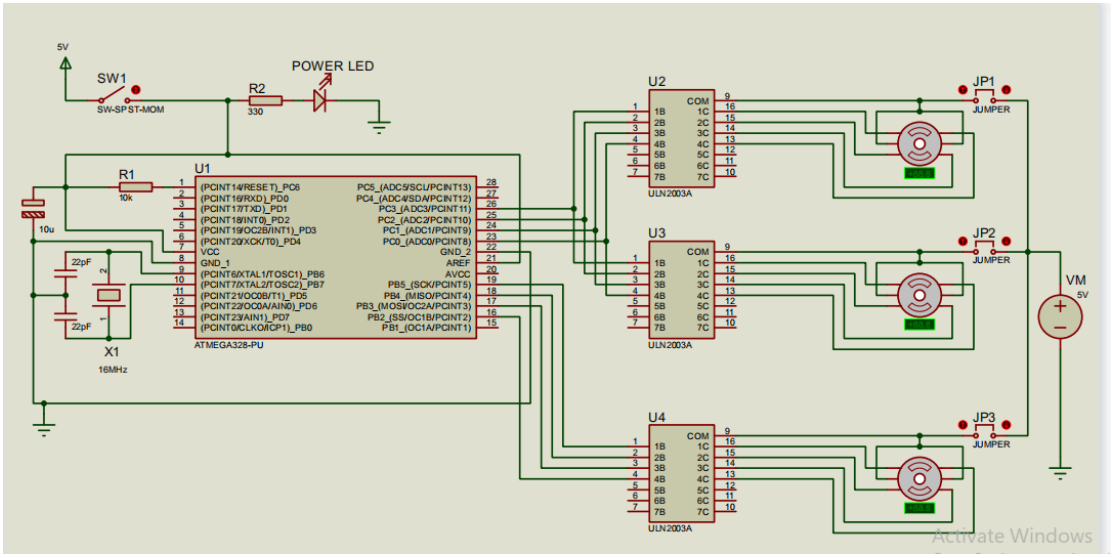


Fig 2.9 Electrical Circuit Outline

The electronic control of this plan was customized utilizing arduino IDE (coordinated improvement climate), and the source code was in written in c++ programming language.

Source Code Given Below:

```
 #include <Stepper.h>
const int stepsPerRevolution = 200;  // change this to fit the number of steps per revolution
const int stepsPerRevolution1 = 200;
// for your motor
// initialize the stepper library on pins 8 through 11:
Stepper myStepper(stepsPerRevolution, 2, 4, 3, 5);
Stepper myStepper1(stepsPerRevolution1, 6, 8, 7, 9);
void setup() {
  // set the speed at 60 rpm:
  myStepper.setSpeed(100);
```

```
 myStepper1.setSpeed(100);
 // initialize the serial port:
 Serial.begin(9600);
}
void loop() {
 // step one revolution  in one direction:
 Serial.println("clockwise");
 myStepper.step(stepsPerRevolution);
 delay(5000);
 // step one revolution in the other direction:
 Serial.println("counterclockwise");
 myStepper1.step(stepsPerRevolution1);
 delay(1000);
  Serial.println("clockwise");
 myStepper.step(-stepsPerRevolution);
 delay(5000);
 // step one revolution in the other direction:
 Serial.println("counterclockwise");
 myStepper1.step(-stepsPerRevolution1);
 delay(1000)}
```

Mechanical Design

Material Consideration and their Properties

i. **Cast Iron:** carbon content 3% to 4.5% by weight, unwinds at around 2100 ºF, glasslike or a granular break.

- **Properties of Cast Iron:** Tensile Strength, High Compressive Strength, Low Melting Point, Resistance to Deformation, Resistance to Oxidation.
-
- **Specification Of Cast Iron**

Density	7.8 $g.cm^{-3}$ at 20°C
Melting point	1536 °C
Boiling point	2861 °C
Atomic mass	55.85 $g.mol^{-1}$
Heat of fusion	13.81 kJ·mol−1

Table 2.1 Cast Iron Specification

ii. **Steel:** High carbon

iii. **Stainless Steels**: Contain alloying augmentations of nickel and chromium,

- **Properties Of Steel**

Yield Strength: 275 N/mm², **Toughness:** The strength of steel and its capacity to oppose fragile break are subject to various elements that ought to be considered at the detail stage.

Ductility: Can be formed to various shapes easily. **Weldability:** The more noteworthy the thickness of material, the more prominent the decrease of sturdiness.

- **Specification of Steel:**

Modulus of elasticity, E	210,000 N/mm²
Shear modulus, G	E/[2(1 + *v*)] N/mm², often taken as 81,000 N/mm²
Poisson's ratio,v	0.3
Coefficient of thermal expansion, *α*	12 x 10^{-6}/°C (in the ambient temperature range).

Table 2.2 Steel Specification

Materials Used, Pictures and Steps:
To convert the rotating motion of the stepper motor into a linear motion, a mechanical linear actuator is used.Mechanical linear actuators typically operate by converting rotary motion into linear motion. The stepper motor is coupled to a threaded rod having a nut which is fixed and does not rotate with the thread; hence whenever the threaded rod rotates the nut is translated in the axial direction of the thread as in a travailing-nut linear actuator.

1. **M5 Stainless Steel Threaded Rod**
   The choice of the material used for threaded rod is stainless steel. It's a stiff material; it has rusting, corroding and staining resistance. The dry surface static/dynamic frictional coefficient is low (static 0.4, dynamic 0.2).

Fig 2.10 M5 Stainless Steel Threaded Rod

2. **Brass Nut:** The choice of the material for the nut is stainless steel. The nut has an internal threaded section.

Fig 2.11 Brass Nut

3. Horizontal Bar.

To make the nut translate in the axial direction of the threaded rod, rotation of the nut must be avoided. To achieve this, the two nuts are carefully glued to the horizontal bar while avoiding misalignment. The horizontal bar is made of aluminum, it is lightweight andrigid.

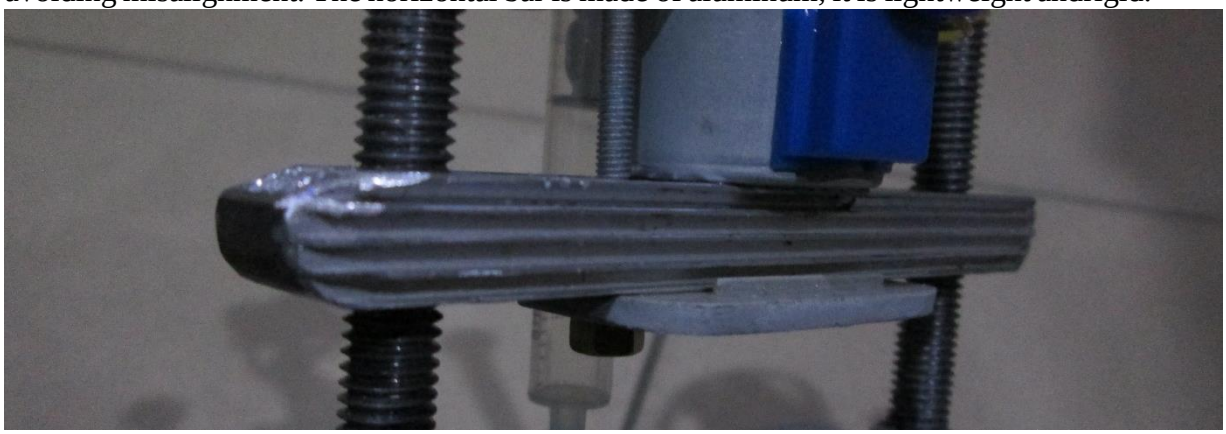


Fig 2.11 Horizontal Bar

4. Coupling The Stepper Motor to Steel Threaded Rod

A cylindrical plastic tube connector with internal diameter 9.2mm is used to couple the stepper motor with the threaded screw. The threaded screw with diameter 7.6mm is fitted 11.5mm deep into the tube such that both centres are aligned; it is then filled with two-part acrylic adhesive.

Connecting the stepper motor with the filled cylindrical plastic, the internal diameter of the connector had to be drilled to 3mm/5mm to fit in the motor shaft.

The above steps were repeated to obtain two couplings for both base stepper motors.

The length of the connector is 20mm.

The length of the motor shaft is 8.5mm. The stepper motors used are the 28BYJ-48 models which have a 6mm flat surface at the axle.

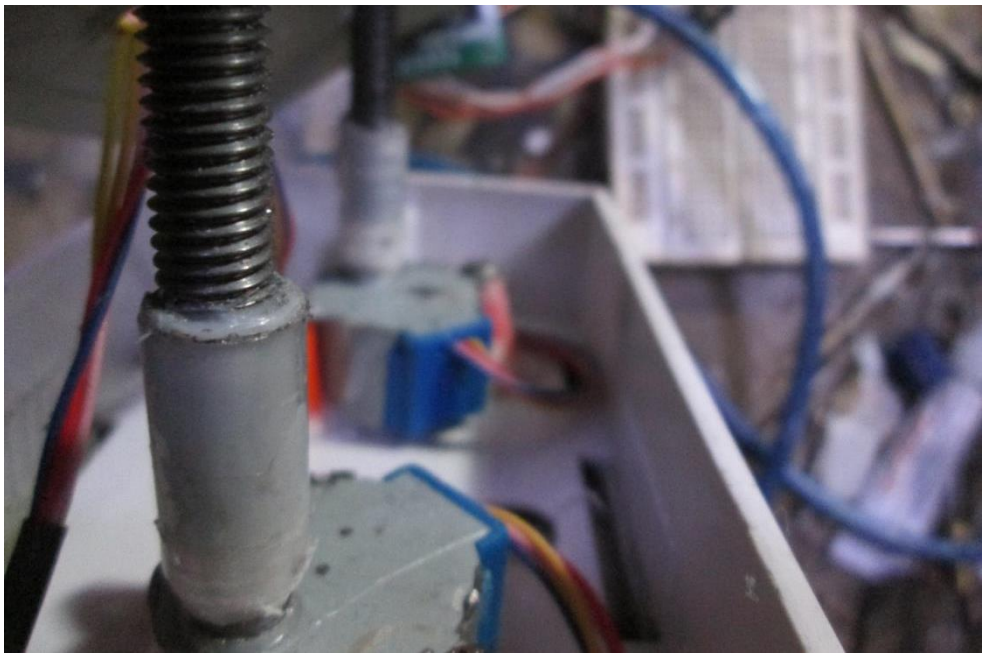


Fig 2.12 Stepper Motor Coupling

5. **Stepper Motors:** Firmly attaching the stepper motor shaft to the connector makes it a stiff coupling that transfers the torque of the stepper motor to the threaded rod.

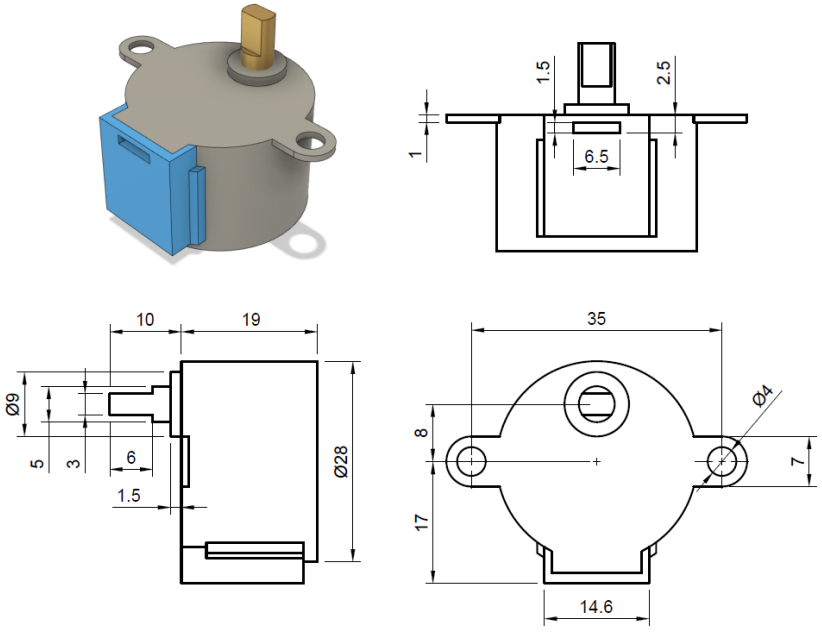


Fig 2.13 Stepper Motor

6. **Base Enclosure:** A 3x6 PVC Parttressbox was used as the base enclosure for housing the electronics control circuit.

Fig 2.14 Base Enclosure (source: wikipedia.com)

7. Strawboard Used to Model The Aesthetic Design of The Device

Fig 2.15 Straw Board (source: wikipedia.com)

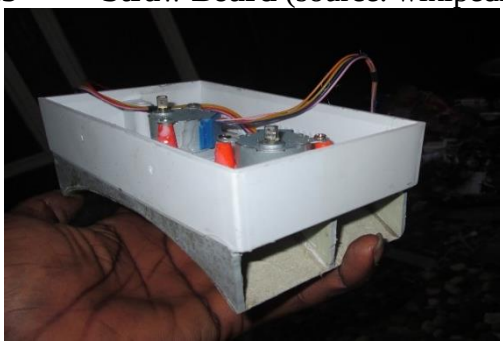


Fig 2.16 Base Designed With Straw Board

2.11 Force Required to Push the Plunger

The diameter of the tube is 1 cm, so the area is .785 cm². That means the plunger travel distance is 25.5 cm = 0.255 m.

The fluid is squeezed down to 200 µm diameter, which is a cross-sectional area of 31.42x10-9 m². The volume of fluid is 20 ml = 20x10-6 m³

$$\frac{(20\text{x}10-6\ \text{m}^3)}{(31.42\text{x}10-9\ \text{m}^2)} = 637\ \text{m}$$

That is how far the 200 µm streams must travel in 20 seconds, for a speed of 31.8 m/s. 20 ml of water has a mass of 20 g, or 0.020 kg. The total kinetic energy that is therefore imparted on the fluid is

$\frac{1}{2}(0.020\ \text{kg})(31.8\ \text{m/s})^2 = 10.1\ \text{J}$

Now we can solve for the force required over the plunger travel distance to impart this energy:

$(10.1\ \text{J})/(0.255\ \text{m}) =$ **39.8 N**

2.12 Torque Calculation

From our design the radius (r) from the rotational axis to the load (syringe plunger) is 1cm away hence, Torque required for application is;

Torque = Force x Distance

30N X 0.01m = 0.3Nm

2.13 Mechanical Coupling

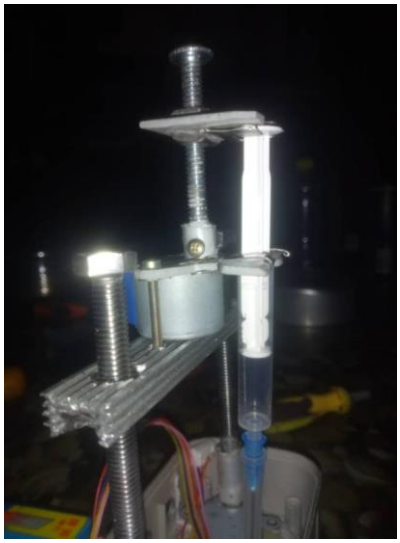


Fig 2.17 (A) Device During Construction

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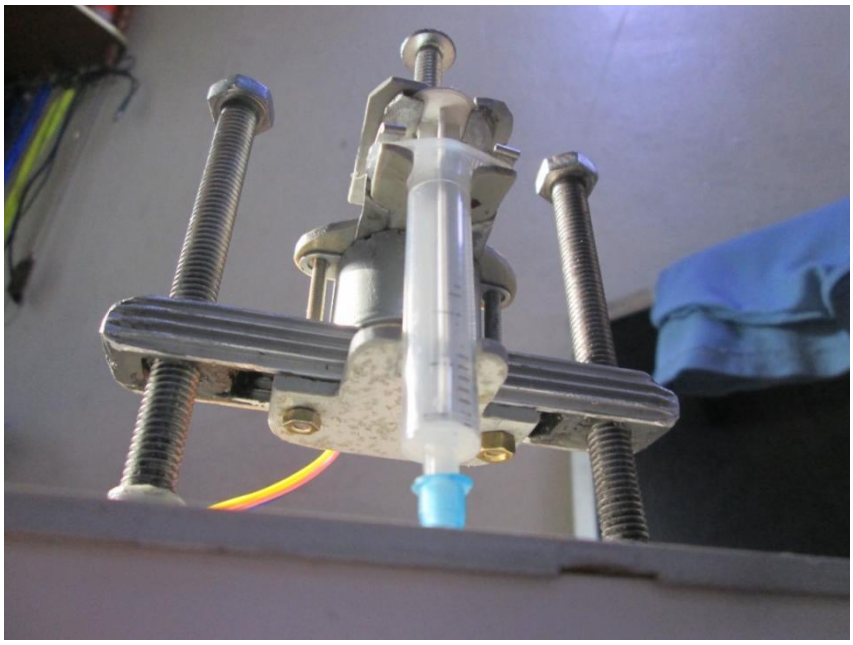

Fig 2.17 (B) Device During Construction

2.14 CAD Parts and Dimensions

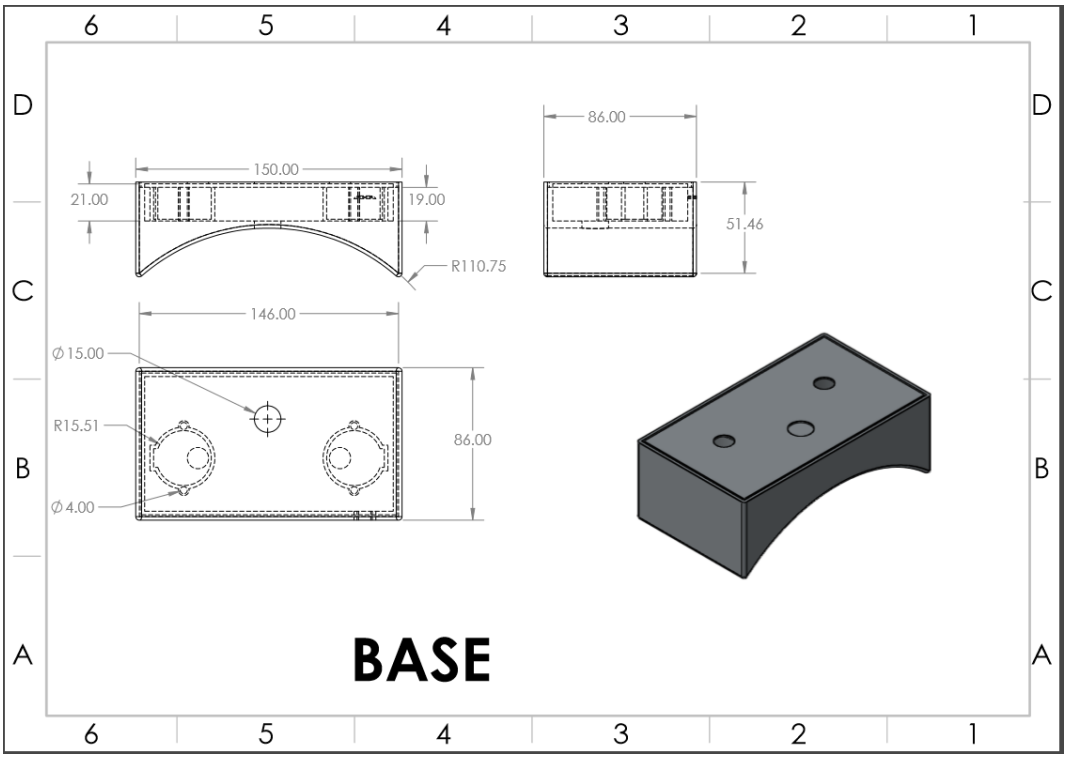

Fig 2.18 Base

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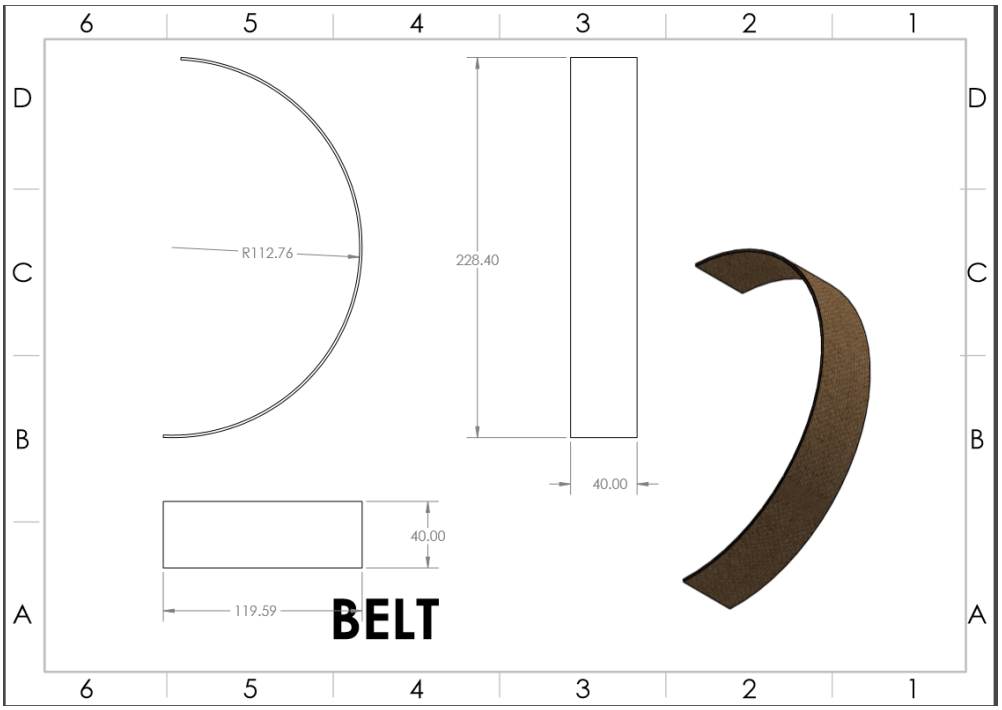

Fig 2.19 Belt

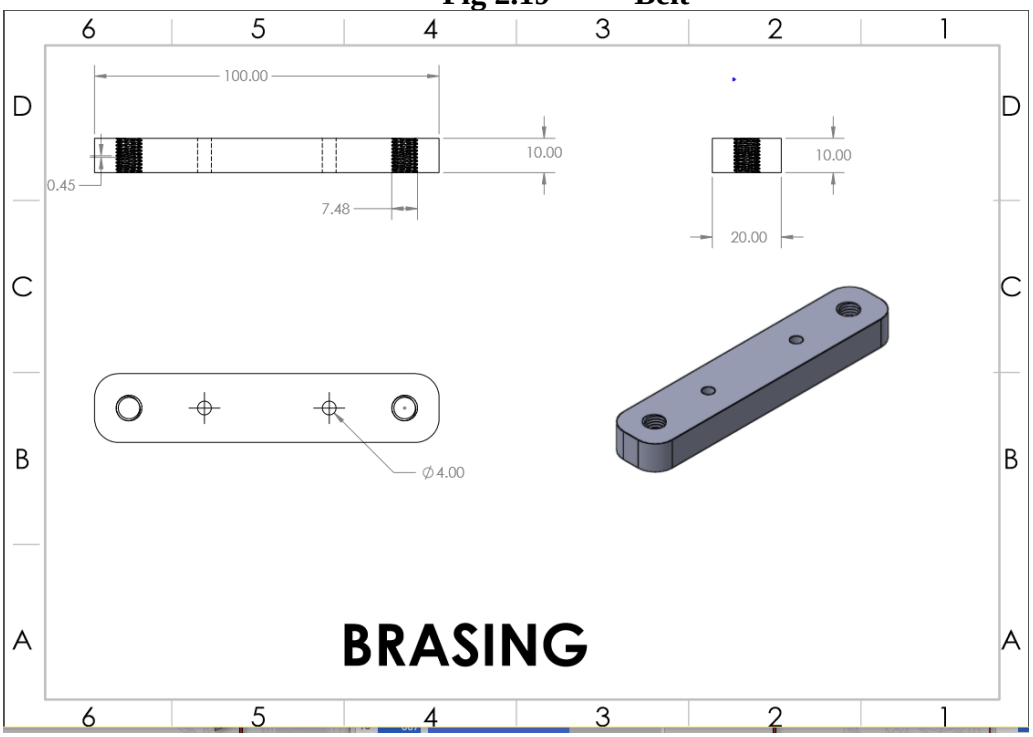

Fig 2.20 Brasing

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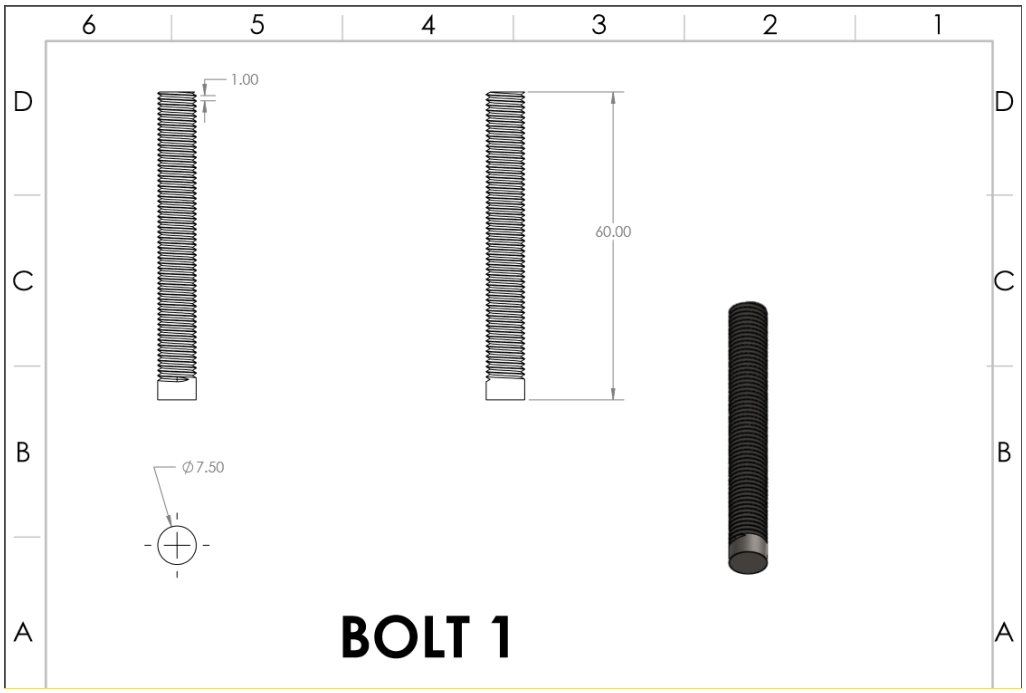

Fig 2.21 Bolt 1

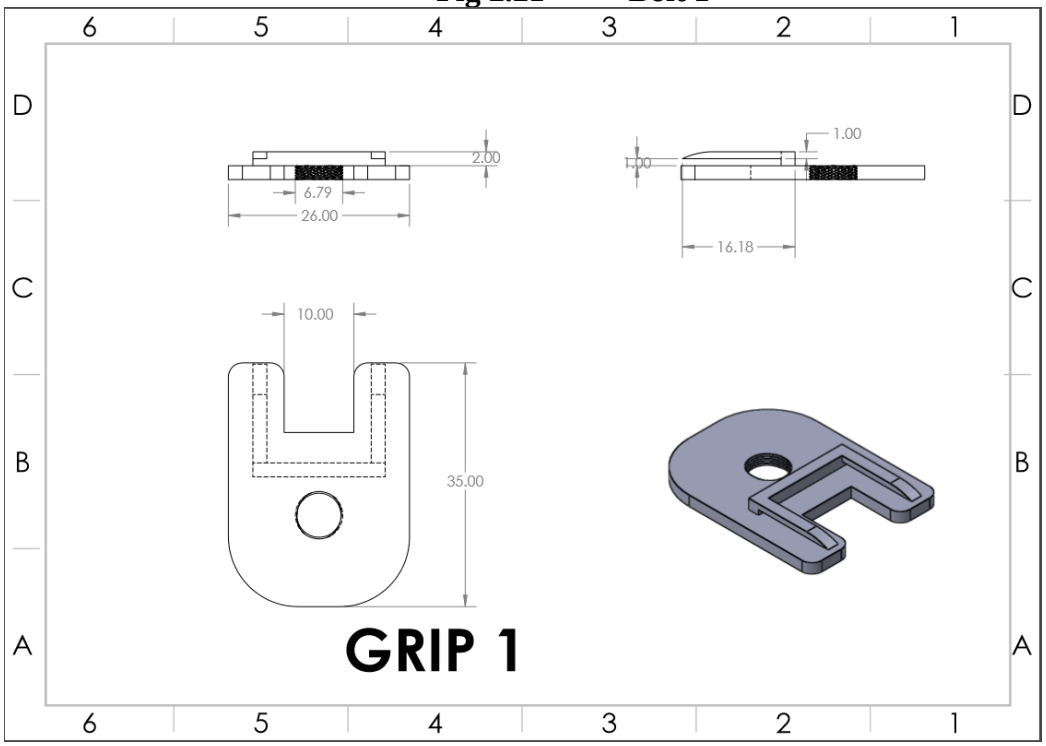

Fig 2.22 Grip 1

European Journal of Biology and Medical Science Research
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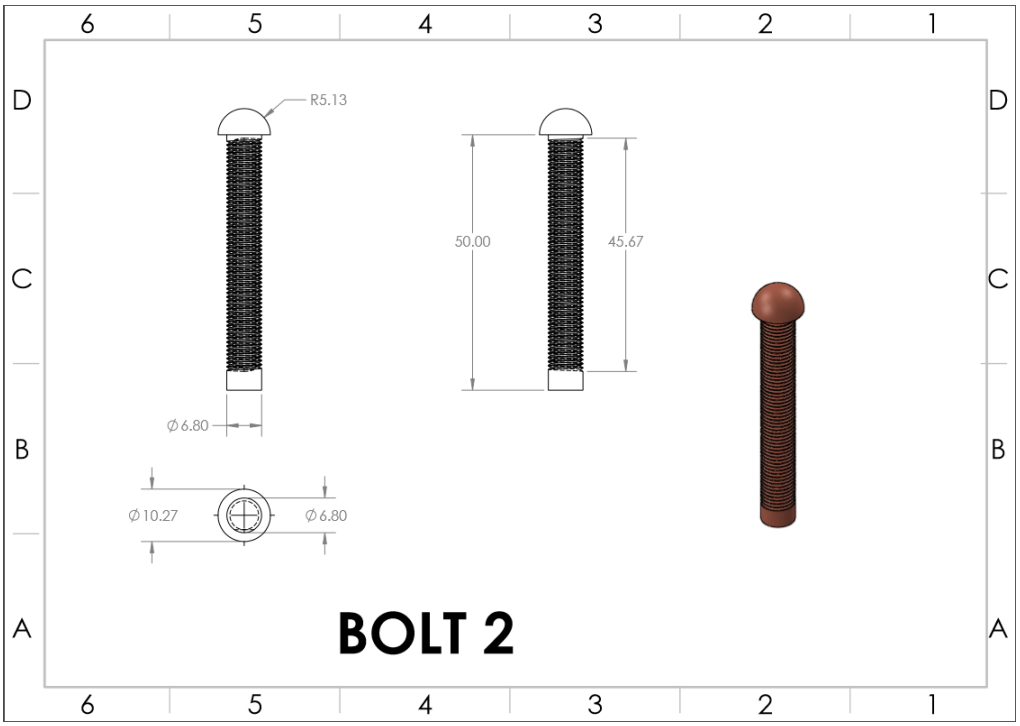

Fig 2.23 Bolt 2

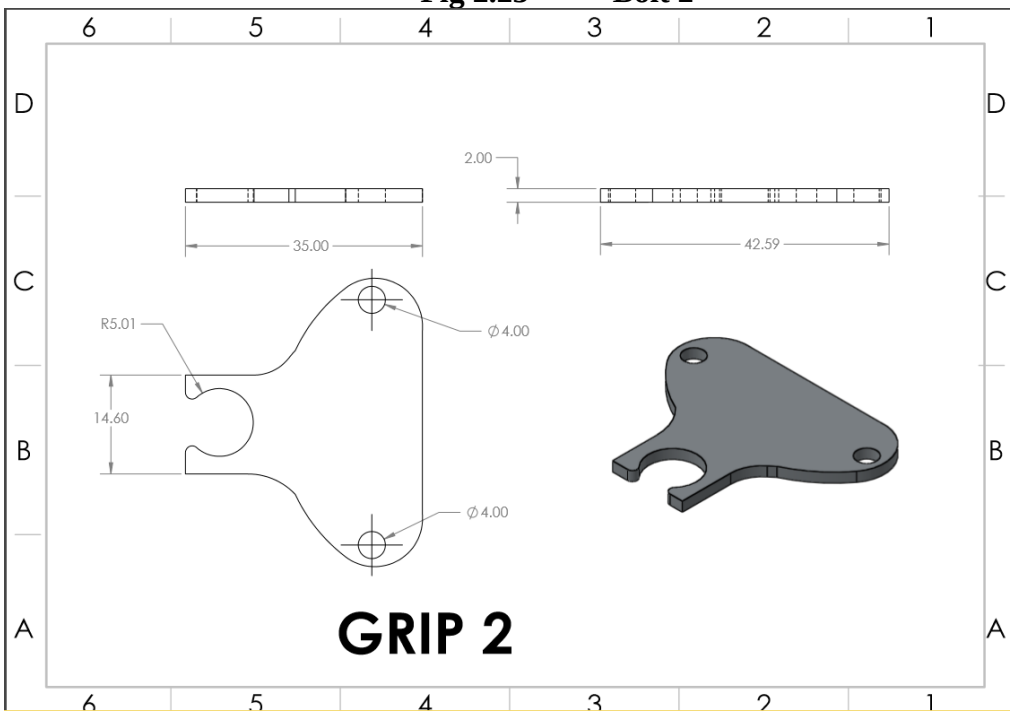

Fig 2.24 Grip 2

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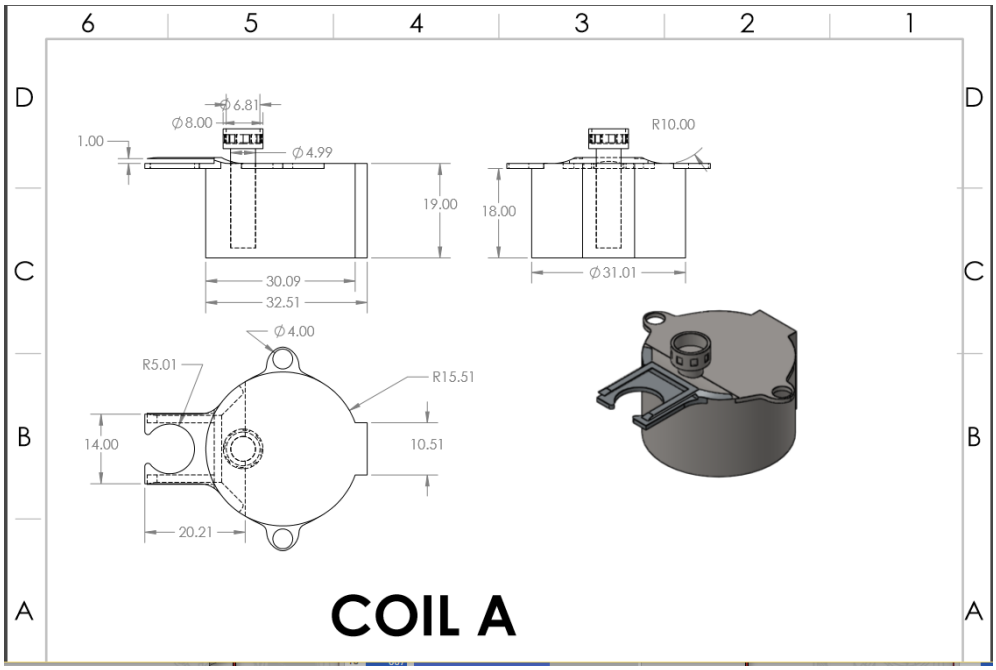

Fig 2.25 Coil A

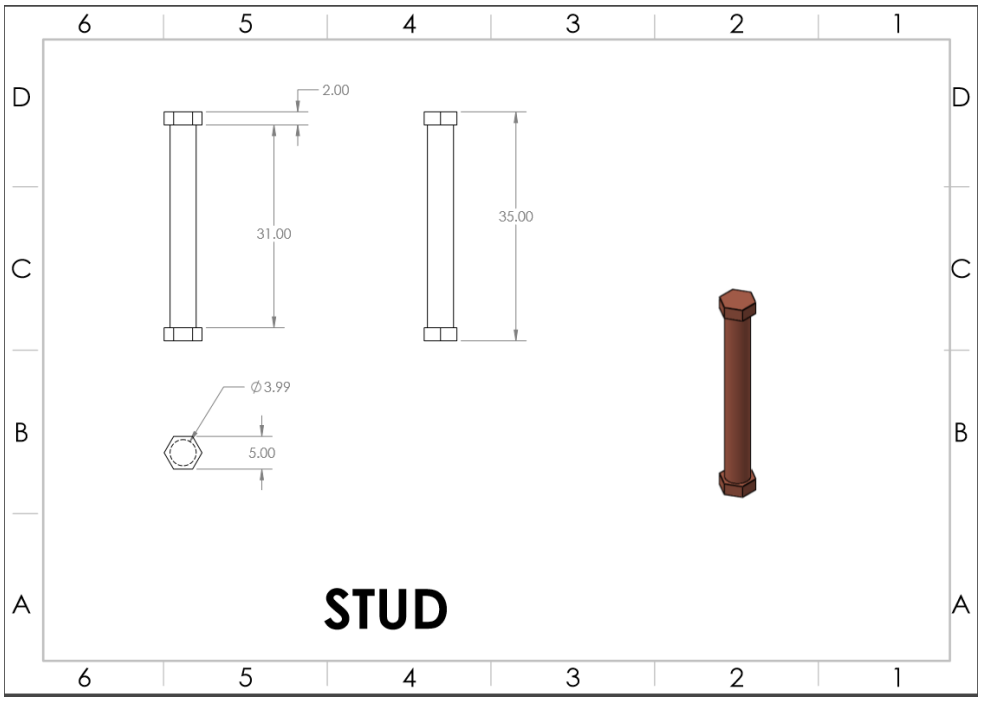

Fig 2.26 Stud

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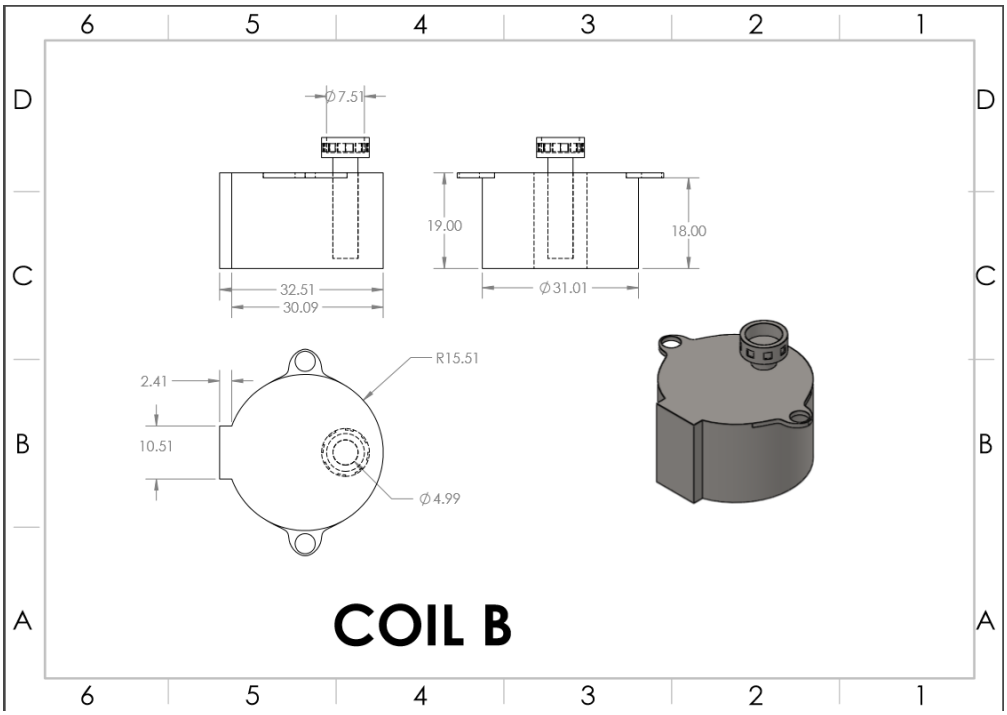

Fig 2.27 Coil B

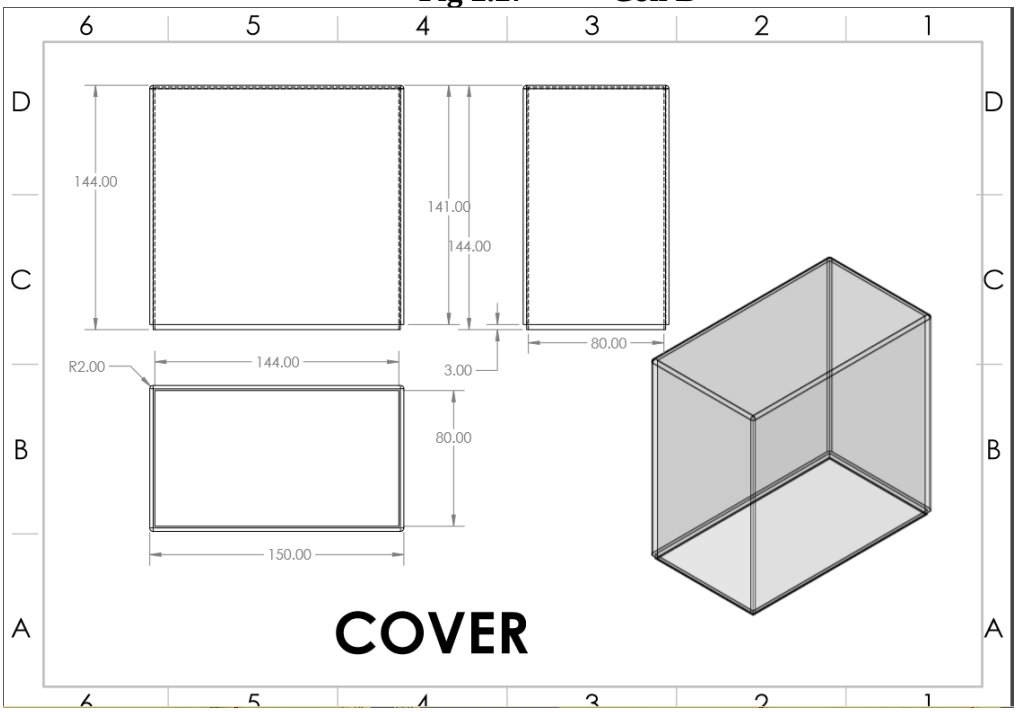

Fig 2.28 Cover

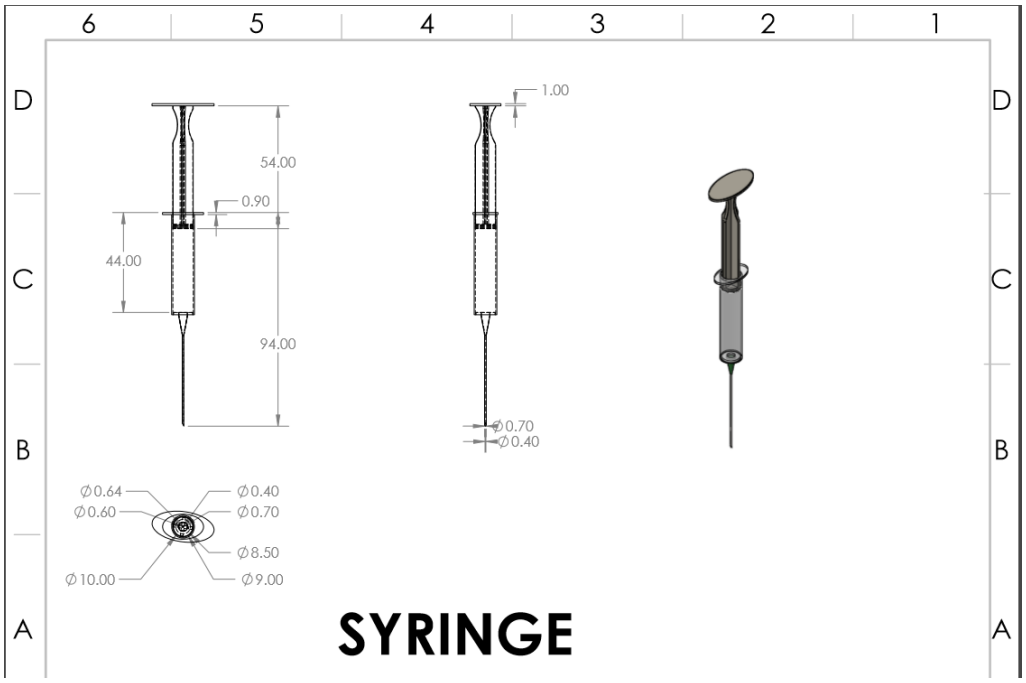

Fig 2.29 Syringe

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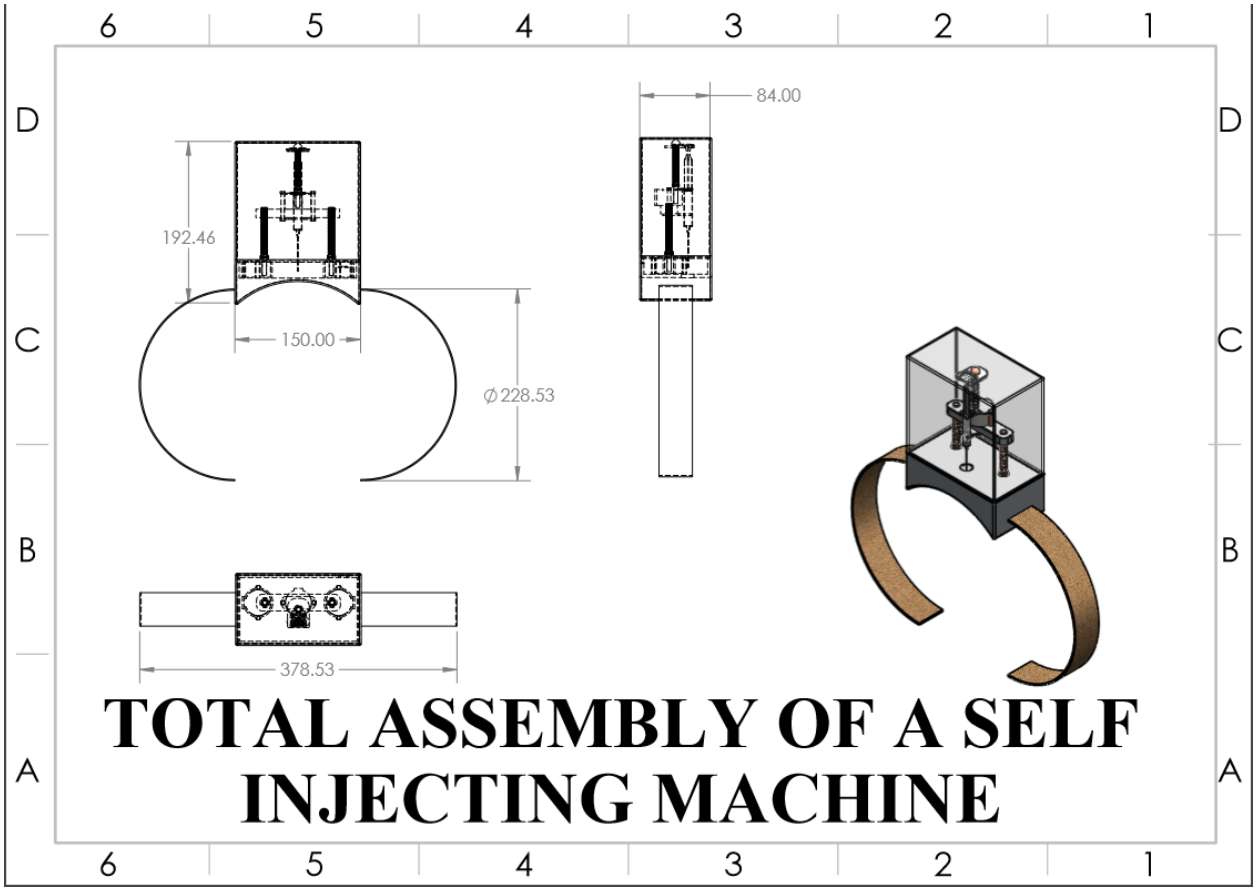

Fig 2.30 Isometric view

3.0 RESULT AND TESTING

3.1 Needle Buckling

During a needle addition, a hub load is applied by the needle to the needle's centre point. This power is opposed by the skin into which the needle is embedded. Under this stacking situation, the needle goes about as a slim walled segment, for which clasping ought to be the most well-known and doubtlessly disappointment mode. Accordingly, it is important to perform mimicked and exploratory clasping investigations on the needles. This gives a benchmark to the most extreme loads that the needle can support before disappointment happens. (Gerald et al., 2003)

3.2 Buckling Finite Element Analysis

3.2.1 Model and Meshing

A limited component investigation (FEA) was performed to decide the heaps that caused the cannula to clasp. This test used the ANSYS Workbench renditions 10.0 and 11.0 programming. The initial step was to make strong models of the needle from the surface models created at SSB. These were created utilizing Solidworks 3D computer aided design programming. From the first plan, which contained similar shape and aspects as the real needle, numerous models

were thusly made, reflecting potential changes in the plan. These models each highlighted various set-ups with changes in the cannula tighten (either tightened or straight), length (38.1 mm, 25.4 mm, or 19.0 mm), and cross sectional shape (round or curved). For the straight needle models, the OD of 0.72 mm was consistent over the length of the cannula. The cross sectional shape mirrors the maths of the real needles, which highlight a curved cross segment, rather than one that is entirely round, which would normally be available in a hypodermic needle. By creating 10 various needle arrangements for FEA testing, it would be feasible to figure out which would be additional compelling practically speaking from a clasping stance. The 38.1 mm length, tightened needle is displayed in Figure 2, and its cross section is displayed in Figure 3.

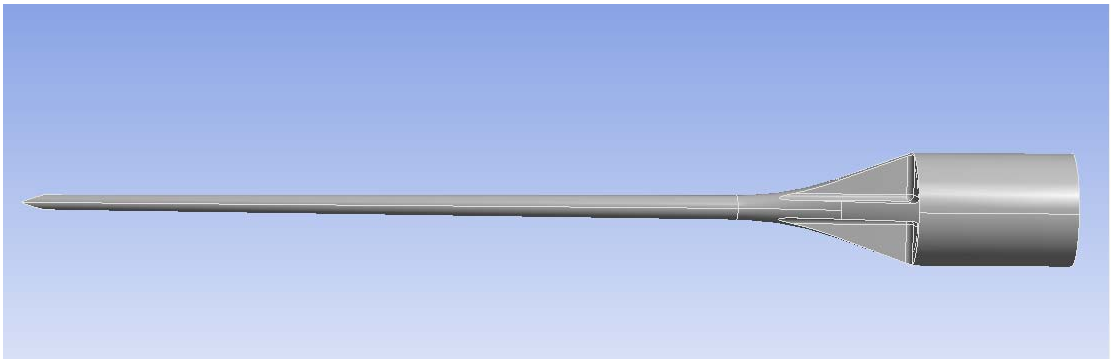

Fig 3.1 - Needle Strong Model Calculation

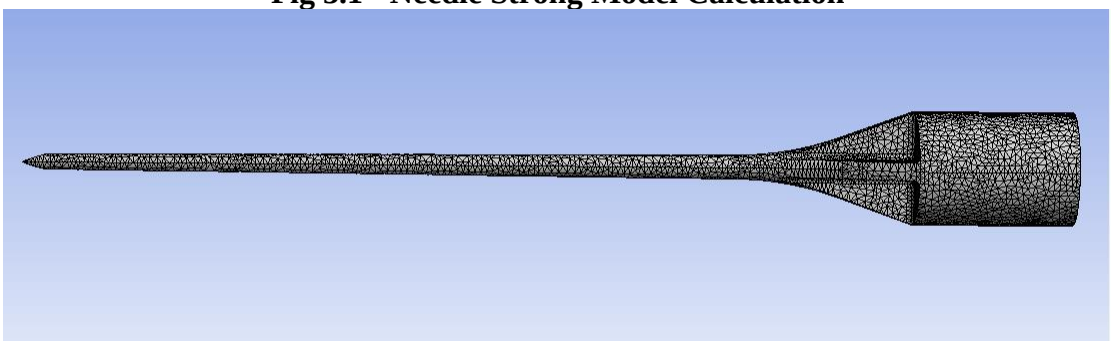

Fig 3.2- Needle Strong Model Lattice

The lattice was created through the "programmed" choice inside the product, making tetrahedral components. Preliminary tests showed intermingling of the answer for a component size of 0.2 mm. The end conditions were picked to mirror those current when a needle enters the skin. In the model, the centre was given a proper end condition, which considers no uprooting or pivot.

This mimics the condition during stacking, in which the centre point is held set up by the needle to which it is connected. The tip was given a decent removal during the recreation. With the direction of the needle adjusted so the length is along the x hub, the relocation was fixed so the y and z tomahawks were confined from dislodging. This permitted free development the x way,

Table 3.1 - buckling FEA results

Length (mm) Blunt	**Cross-Section**	**Taper**	**Sharp tip load (N)**	**tip load (N)**
38.1	Circular	Tapered	7.88	4.86
38.1	Elliptical	Tapered	6.68	3.19
38.1	Circular	Straight	2.88	1.73
38.1	Elliptical	Straight	2.94	1.31
25.4	Circular	Tapered	15.64	11.08
19.0	Circular	Tapered	26.17	20.12
25.4	Circular	Straight	6.36	4.11
19.0	Circular	Straight	11.14	7.76
25.4	Elliptical	Tapered	13.44	7.33
19.0	Elliptical	Tapered	24.63	13.42
25.4	Elliptical	Straight	6.44	3.13
19.0	Elliptical	Straight	12.92	5.97
38.1	Circular	(1/3) Tapered / (2/3) Straight	4.01	-
38.1	Elliptical	(1/3) Tapered / (2/3) Straight	3.11	-
38.1	Circular	1 (1/2) Tapered / (1/2) Straight	4.46	-
38.1	Elliptical	(1/2) Tapered / (1/2) Straight	3.53	-

just as free revolution about any of the three tomahawks, reproducing a stuck joint end condition. These requirements on the development of the needle imitated its movement during starting contact with the skin. The heap acting along the needle was mimicked in the FEA by applying a guide load toward the tip, acting along the x hub. A heap of 1 N was applied, which was utilized to "scale" the investigation. The needle models have the material properties (flexible modulus, Poisson's proportion, yield strength) found in Reference section D. (Gerald et al., 2003)

3.2.2 FEA Results

The outcomes from the FEA incorporate a heap factor, which is a multiplier that, when increased by the applied power, gives the genuine clasping load. By contributing 1 N as the applied burden, the yield will be the genuine clasping load for the first clasping mode. The FEA conditions and results are summed up in Table 4.1. For correlation, two tip conditions were reproduced – sharp and gruff. This empowered the impact of the presence of the tip on the outcomes not really set in stone. An agent consequence of the twisting, showing a tightened 38.1

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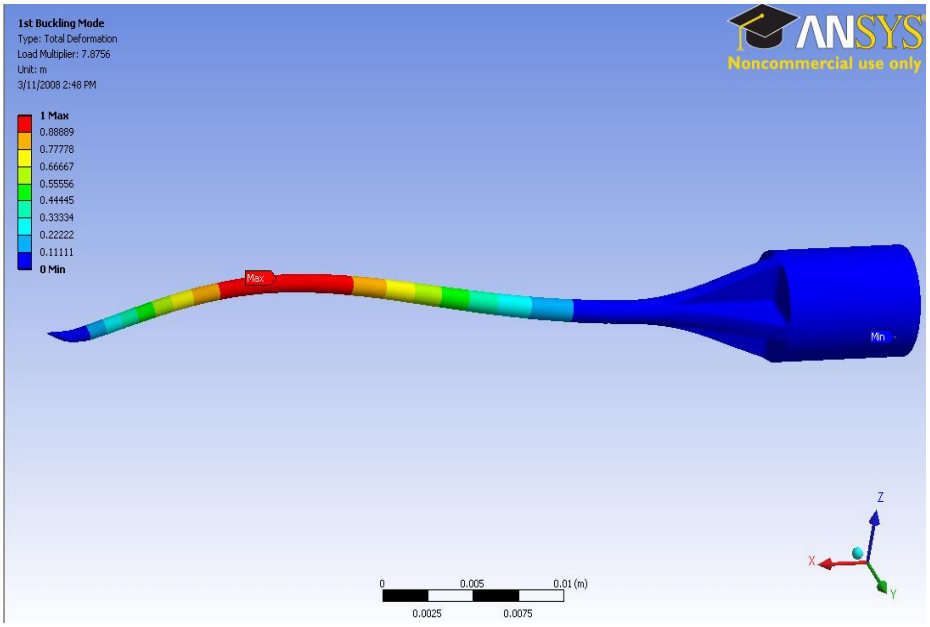

Fig 3.3 - Needle misshapening in ANSYS clasping recreation (38.1 mm length,tightened cannula, round cross area)

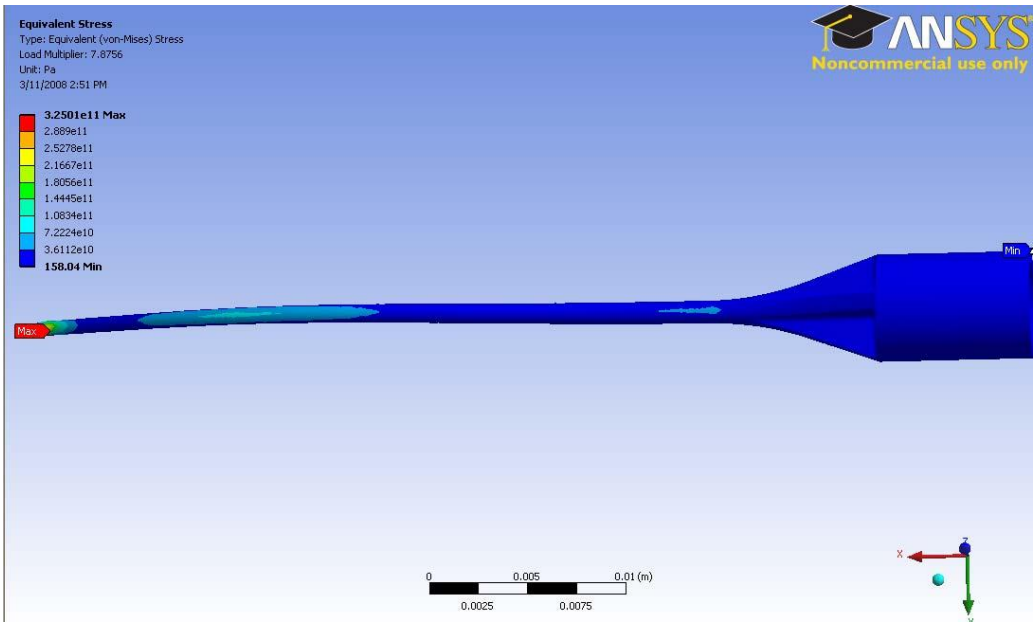

Fig 3.4 - von Mises pressure conveyance in ANSYS clasping recreation (38.1 mm length, tightened cannula, roundabout cross segment)

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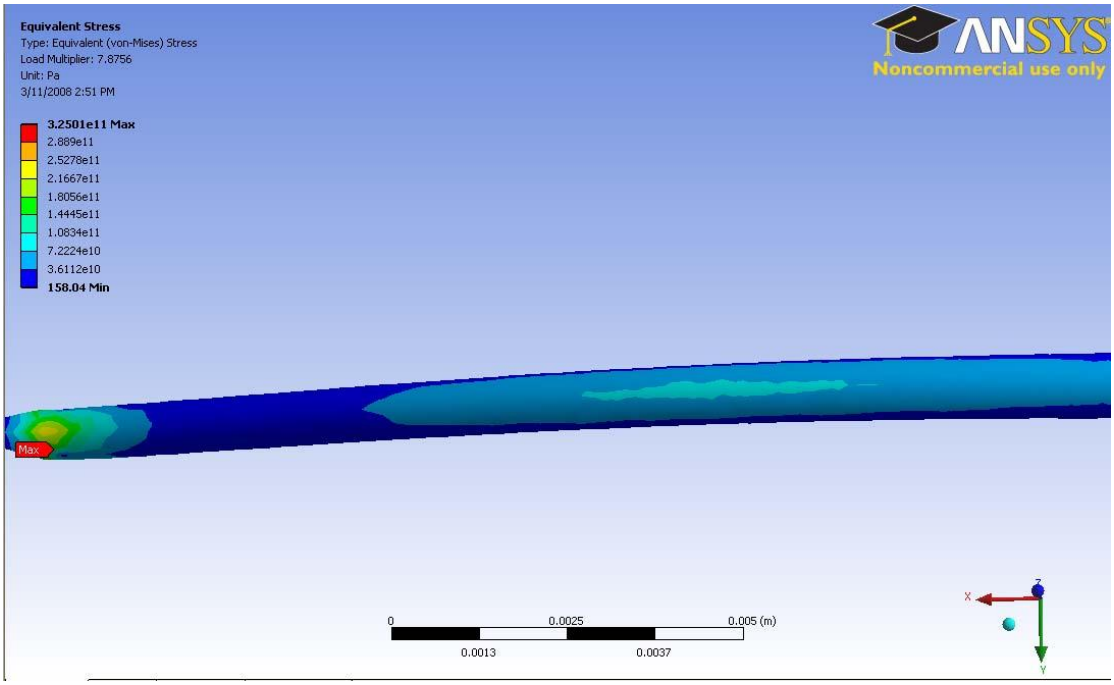

Fig 3.5 - von Mises pressure at needle tip (38.1 mm length, tightened cannula, roundabout cross segment)

The clasping re-enactments showed many patterns concerning the impacts of the factors. For the two hints, the tightened needles had a clasping strength 125-175% more noteworthy than the straight needles of a similar length and cross segment at the tip due to the expanded breadth at the canter. Moreover, needles that had a joined straight/tightened cannula (directly at the tip, tightened close to the canter) had qualities between those of the straight needles and those of the tightened needles, with the strength expanding as the length of the tightened area increments. For tightened needles, a circular cross area has a clasping strength 6-17% lower than the round cross segment (here the significant hub of the curved cannula is a similar size as the breadth of the barrel shaped cannula). Notwithstanding, for circular, straight needles, the contrary pattern exists; the clasping strength is 1-17% higher than the curved, tightened needle's solidarity. Changing the length likewise largely affected the clasping qualities. Lessening the length from 38.1 mm to 25.4 mm expanded the strength 98-120%. Further diminishing the length from 25.4 mm to 19.0 mm expanded the strength another 68-100%. Eliminating the tip yields a reduction in the clasping power for all needle plans with the given end condition. These outcomes give a reach to the consequences of genuine clasping tests. The outcomes likewise show a distinction in the clasping loads between the sharp tipped model and the unpolished tipped model. For each needle design, the models with sharp tips reliably show a 30-109% higher clasping load than the dull tipped models. This is valuable in that it shows that under the conditions under which the needles are oppressed, they are more grounded than conventional segments. This outcome might be because of the space on which the heap is set, in particular, the whole tip. The scope of these outcomes gives a sensible gauge of the real clasping strength of the needles.

15 In this manner, from an unadulterated clasping viewpoint, the 19.0 mm since quite a while ago tightened needles would be generally good for execution. This is normal, as section clasping hypothesis would prompt the end that more limited segments have higher clasping loads on the grounds that the basic burden increments as the segment's length diminishes. Additionally, the tightened sections highlight more material than straight segments and can thus oppose higher pivotal burdens. In any case, from a more common-sense view, these needles might be too short to possibly be compelling for some employments of hypodermic needles. Hence, albeit the recreated clasping loads are a variable in the assurance of the most fitting needle, different types of testing are needed to settle on the most ideal decision for an appropriate plastic hypodermic needle. (Medical Device Technology, 2003).

3.3 Needle Penetration – Theory and Simulations

A needle inclusion is performed by driving the needle against an article until it enters. This is one of the two essential objectives of a hypodermic needle infusion, with the other being the protected conveyance of the liquid communicated through the needle either to or from the item getting the inclusion. Subsequently, it is pivotal to show that the plastic needles are equipped for infiltrating skin. This includes both PC displaying and tests. In this section, FEA re-enactments will display the needle's capacity to enter a skin emulate, and the FEA results will be checked by entrance tests. The hypothesis behind needle entrance additionally will be talked about. (Price et al., 2006)

3.3.1 Penetration Theory

Needle infiltration into human skin (or a skin substitute) can be separated into three parts. The primary part, a trampoline impact that happens as the heap sent from the needle builds, happens preceding infiltration. This comprises of the skin hanging nearby the needle while the needle proceeds descending against the skin. The subsequent part, the actual infiltration, is described as a tearing of the skin as the needle penetrates it. These two parts of needle infiltration are diverse mechanical capacities and are depicted by two autonomous arrangements of conditions in this proposition. The third part is the sliding that happens following the entrance. This part is exceptionally factor contingent upon the needle's grease and the entered medium. Conditions were not produced for this last frictional power. (Gerald et al., 2003)

3.3.2 Bending Prior To Penetration

The main part of infiltration is a joined activity of skin bowing and extending. During a needle infiltration, skin inside a limited locale of the entrance is twisted by bowing and extending, while skin outside this area is unaffected. To recreate this conduct utilizing an elastic skin emulate, the elastic is clipped set up, leaving an uncovered region in the middle where the infiltration and restricted disfigurement happen. With this actual imperative applied, the twisting addresses the adjustment of the point of the sheet from level over the long haul from where it is in touch with the needle to where it is clasped in the supporting installation, and the extending addresses the adjustment of distance between those two areas. The twisting, outlined in Figure 4.6, is like sheet metal bowing, in which a punch is brought down onto a level sheet

of metal and curves it into the state of the bite the dust underneath. The extending is comparable to an elastic burden applied to the edges of a plate.

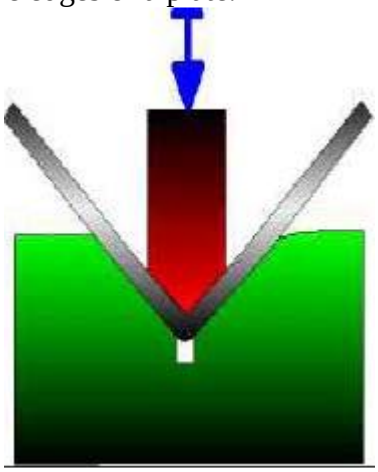

Fig 3.6 - Schematic of sheet metal twisting

Table 3.2 - Properties of Skin

Layer	Thickness (mm)	Elastic Modulus (MPa)
Stratum Corneum	0.01-0.02	12000
Living Epidermis	0.03-0.13	16
Dermis	1.1	12
Subcutaneous Fat	1.2	20

Embedding the known upsides of the polyurethane material properties, into equation 12 in chapter three yields the most extreme burden achieved before plastic strain in the polyurethane. With a deliberate needle tip span of 0.043-0.065 mm, the determined entrance load goes from 3.98-7.33 N.

3.3.3 Assurance of Hypothetical Entrance Power

Subbing the important qualities into equations 13-15 yields the necessary power for entrance to happen. As the break durability for polyurethane was ridiculous, values like those of silicone elastic (9100 N/m) and human skin (2500 N/m) were picked, and the entrance not really set in stone. Likewise, the shear modulus was fluctuated to acquire a more precise scope of information for the entrance power. With polyurethane as the skin imitate, this power shifts from 1.6-3.5 N. The trial tests in Part 4 will check the legitimacy of these qualities for the entrance power. The 29-infiltration power in polyurethane is displayed as an element of the conceivable crack strength esteems in Table 4.3. Likewise shown are the powers needed to make the air out and to the break in the elastic. For human skin, utilizing known properties, the entrance power is around 1.9 N. These numbers can change dependent on the strength of the

penetrating gadget, tip plan, and grating; however, they give a premise to gauge the entrance power.

Table 3.3 - Hypothetical Entrance Load In Polyurethane

JIC (N/m)	Penetration Force (N)	Force to Create Crack (N)	Force to Open Crack (N)
2000	1.63	0.72	0.91
4000	2.17	0.86	1.31
6000	2.65	0.86	1.78
8000	3.05	0.57	2.48
10000	3.53	0.72	2.81

These outcomes demonstrate that as the crack strength builds, the required infiltration power increments. What's more, the general power needed to make a break in the elastic under these infiltration conditions remains moderately steady. This is fundamentally because of the mix of expanded work in making the break in a harder material and a diminished break size as strength increments. Nonetheless, the necessary power to open the break increments consistently as the crack strength increments. This happens on account of the diminished break size found in the harder material. As the underlying break made is more modest, more power is then needed to grow the break to acquire the opening size essential for needle addition. (Oomens et al., 2001)

3.3.4 Penetration Simulation Results

Two unique models were run for the entrance recreations. The first, depicted above, demonstrated the needle as a deformable body. The second demonstrated the needle as an inflexible body.

Two distinct models were run for the entrance reproductions. The first, portrayed above, displayed the needle as a deformable body. The second demonstrated the needle as an inflexible body. The infiltration re-enactment showed that the needle ought not have the option to enter the polyurethane, much under frictionless conditions. Regardless of changes in the code that would consider more prominent deformity than the defaults, hence making an unreasonable deformity condition, the reproduction cut short because of unnecessary disfigurement in the needle, explicitly around the space of the tip. This 34 demonstrates that either changes in the tip plan or a decrease in the length of the needle is vital for effective infiltration. Albeit the disappointment happened close to the tip, as found in F, it very well may be because of flimsiness brought about by the length of the needle. It is additionally clear in Figures 4.7 - 4.10, which show the needle with the elastic eliminated at various time steps in the infiltration, that the von Mises pressure dispersion all through the needle is fundamentally lower than the burdens found at the tip where the needle disfigured.

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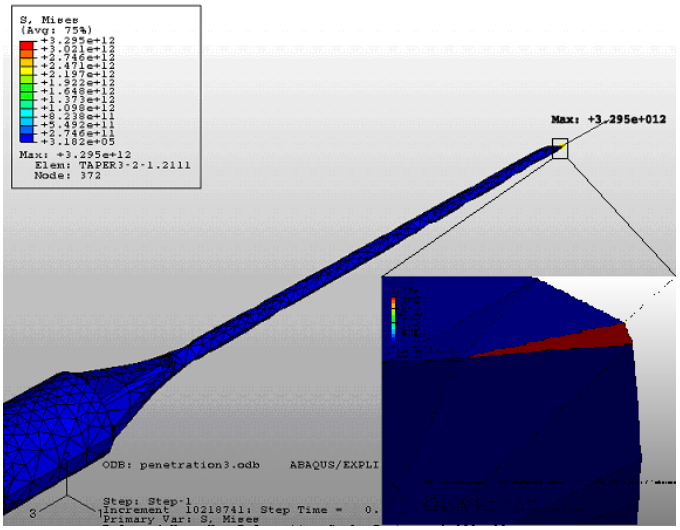

Fig 3.7 - Area of disappointment during entrance recreation at 0.298 seconds (note the exorbitantly focused on component on the tip)

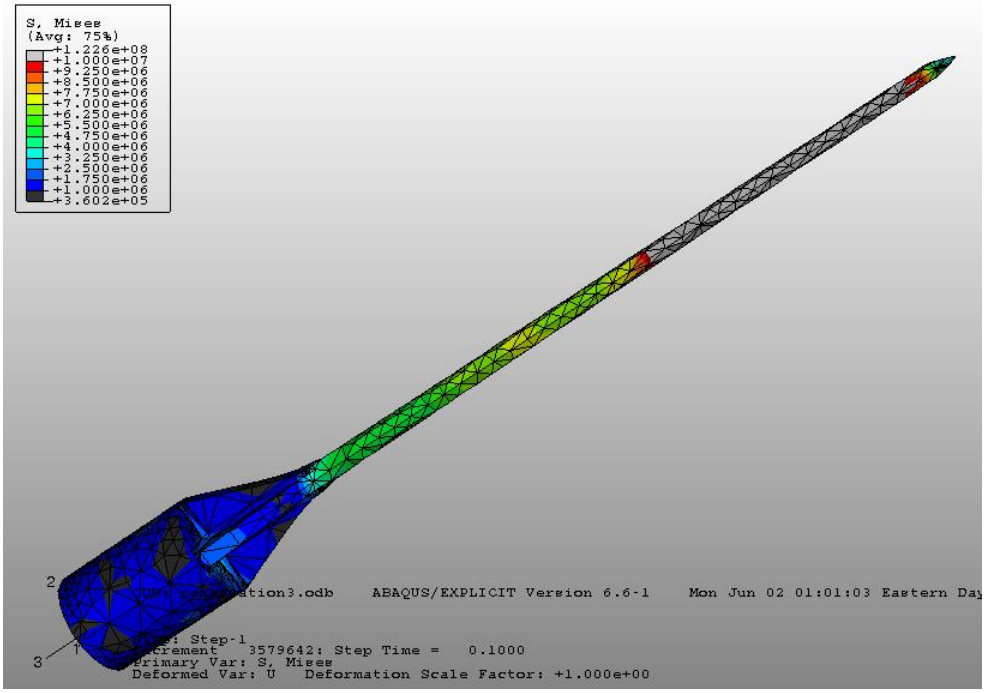

Fig 3.8 - Stress circulation in needle at 0.1 seconds during entrance

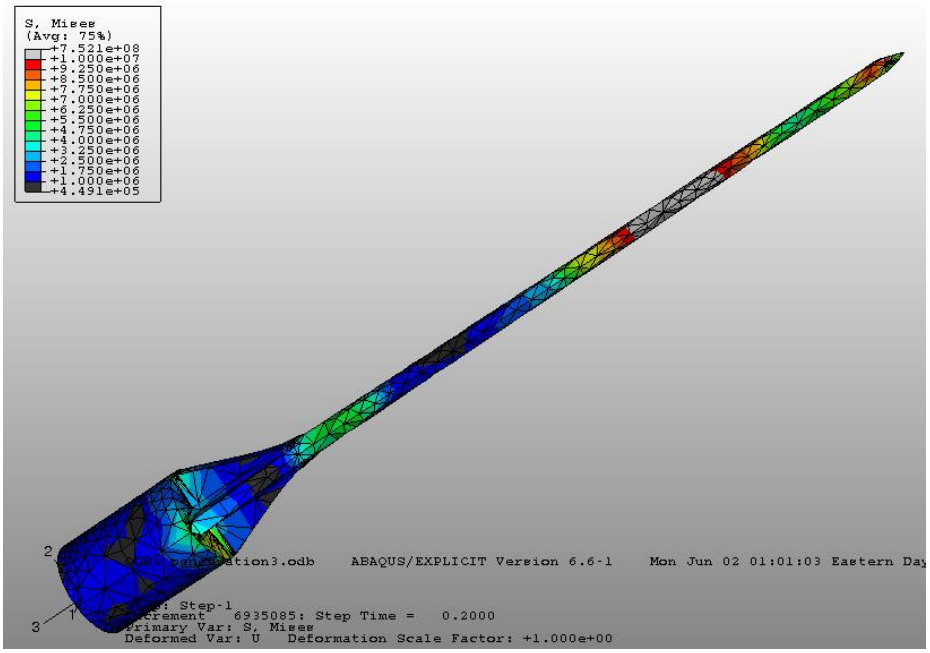

Fig 3.9 - Stress circulation in needle at 0.2 seconds during entrance

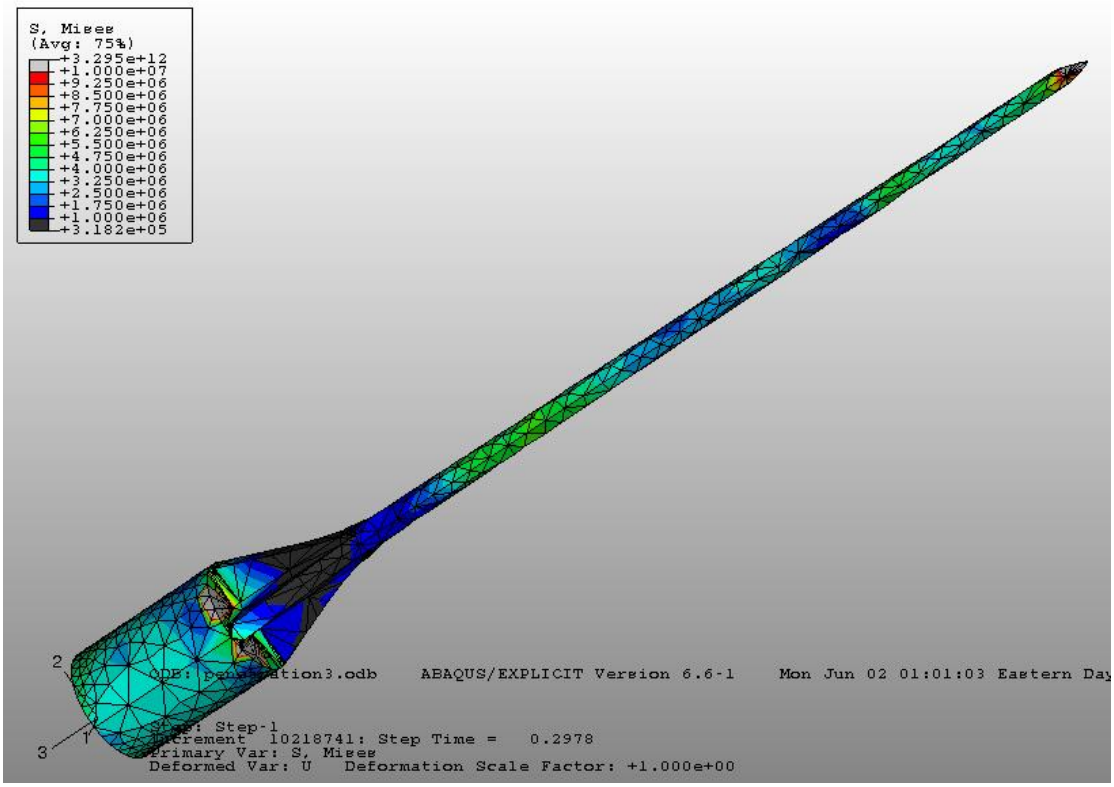

Fig 3.10 - Stress circulation in needle at 0.298 seconds during entrance

A pressure of 3300 GPa was determined close to the tip right now of disappointment. The stresses all through the rest of the needle didn't surpass 100 MPa, and were extensively lower in many regions. Stresses along the cannula changed for each time venture, as displayed in Figures 4.7 - 4.10, however never arrived at a level that would cause disappointment in the cannula. With tip disappointment happening at around 0.3 seconds into the endeavour infiltration, these outcomes don't exhibit how the needle will respond further along into the entrance. Should tip disappointment happen during the trial along these lines as the recreation, information can keep on being gathered until the needle eventually clasps. Be that as it may, the re-enactment is told to end once a quantifiable disappointment happens, and the pressure conveyance in the cannula for the rest of the infiltration can't not really settled. As infiltration into a skin impersonate had not happened during this re-enactment, the needle was demonstrated as an inflexible body to forestall deformity and potentially permit entrance to happen. In this way, it still up in the air whether a precise needle infiltration model can be produced utilizing the inflexible body condition. (Oomens et al., 2001)

3.4 Penetration Simulation Results

3.4.1 Rigid Body Needle Results

To apply a heap to an unbending body, one point on the body should be chosen as an unbending body reference hub. This is as opposed to the space over which a heap can be applied to a deformable body. While the heap was applied to the whole canter point for the past re-enactment, this recreation required a level surface covering the canter point to take into consideration the heap to be set at its lope. As the needle is an unbending body, this won't influence the outcomes at the area where the needle contacts the elastic. By approximating the needle as an unbending body, the re-enactment had the option to display needle infiltration into the elastic. The re-enactment showed that entrance would start to happen after around 2.7 seconds, when it exhibited quick component twisting in the lope of the elastic near the needle's addition point. The outcomes over the long haul are displayed in Figures 4.11 - 4.14, with the time step quickly preceding inclusion, before component twisting, displayed in Figure 4.11. Figure 4.12 shows the pressure dissemination in the elastic for this time venture, with the needle eliminated.

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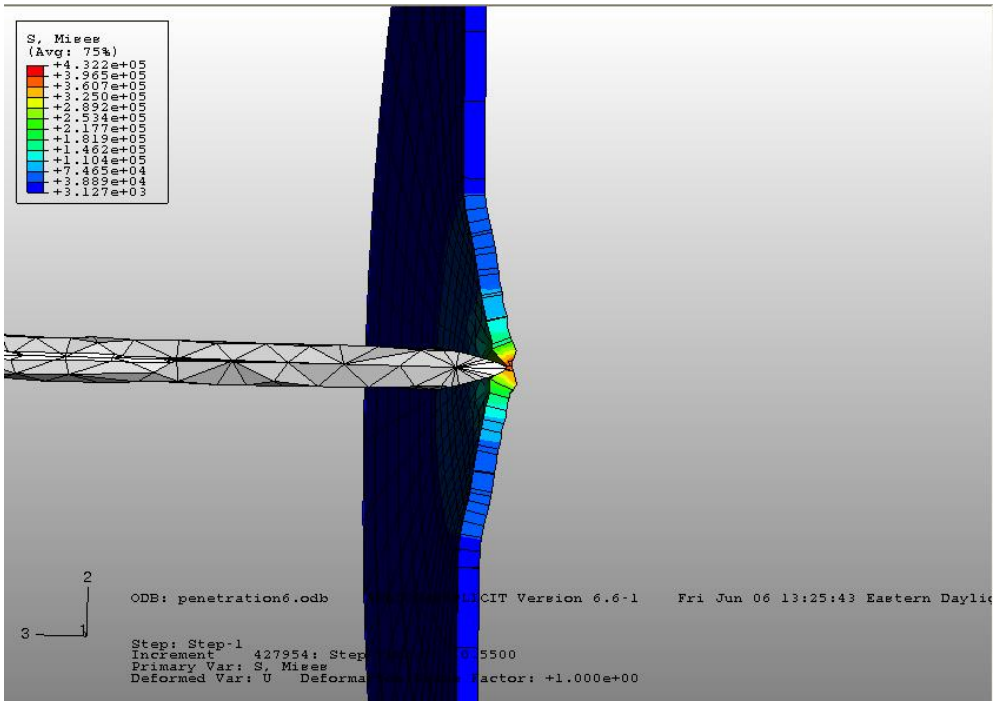

Fig 3.11 - Area perspective on unbending needle infiltrating elastic skin copy at 0.55 seconds

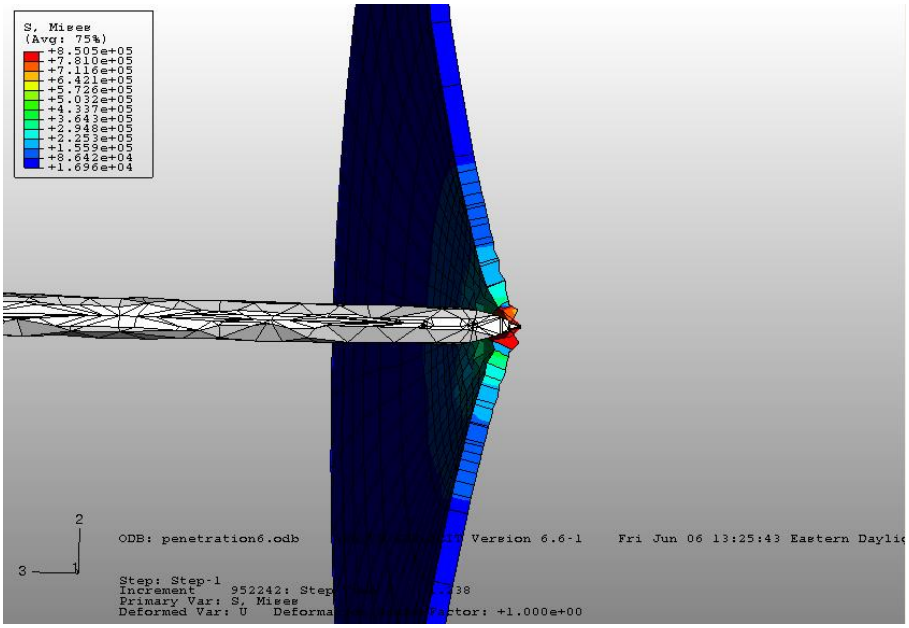

Fig 3.12 - Area perspective on inflexible needle infiltrating elastic skin emulate at 1.24 seconds

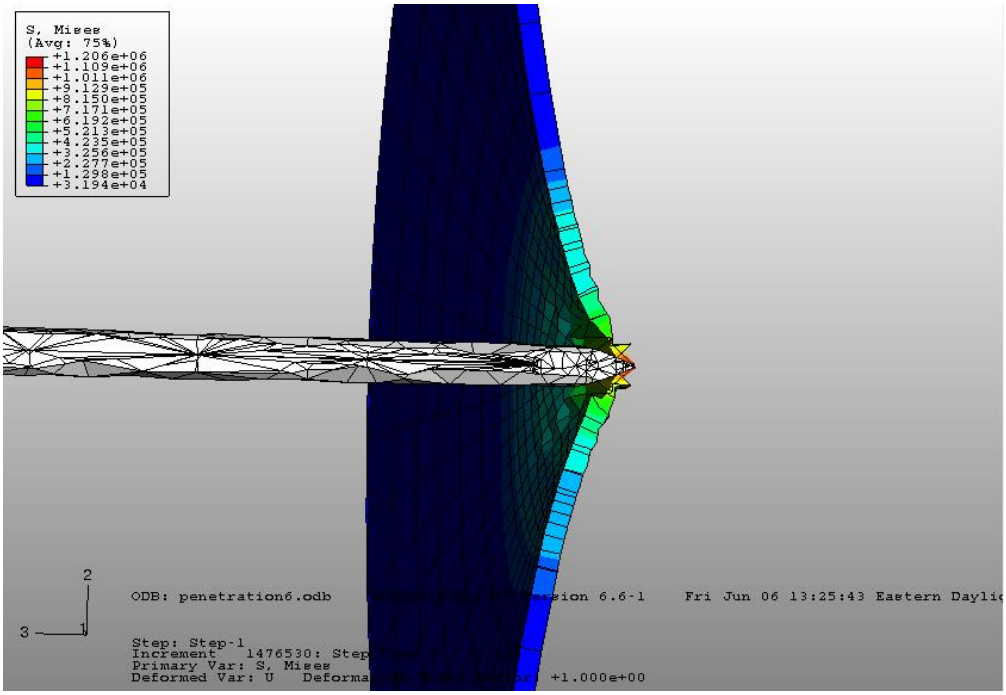

Fig 3.13 - Area perspective on inflexible needle infiltrating elastic skin emulate at 1.93 seconds

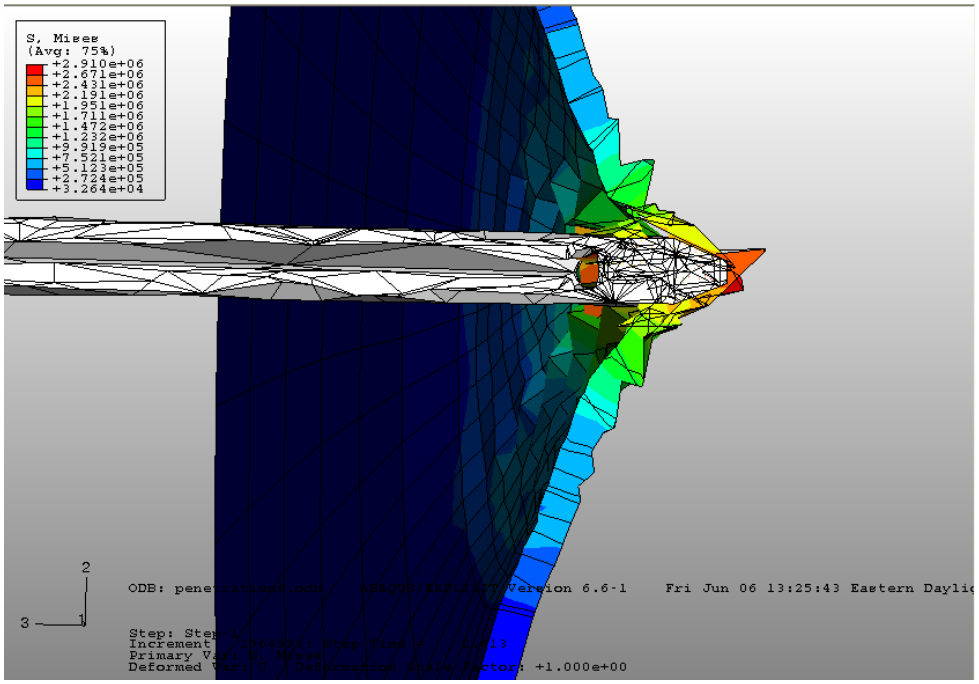

Fig 3.14 - Area perspective on inflexible needle infiltrating elastic skin emulate at 2.61 seconds

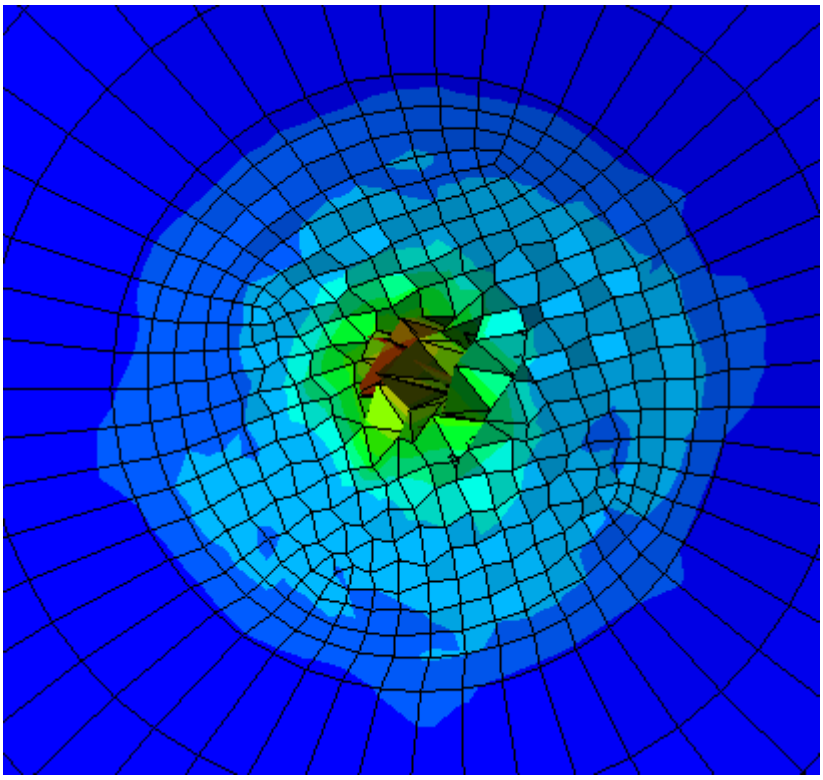

Fig 3.15 – Stress circulation of elastic skin imitate at 2.61 seconds after needle addition

The outcomes show the von Mises pressure circulation all through the elastic as the needle is embedded into the elastic. Figures 4.13 - 4.14 show a slowly expanding pressure circulation all through the elastic during entrance. As the needle is portrayed as a unbending body, no pressure estimations are performed for the needle, and no twisting happens inside the needle. True to form, the most elevated pressure and misshapening in the elastic happen nearest to the needle addition area. Infiltration doesn't happen until the strain arrives at as far as possible, as determined in the material portrayal. With an accepted plastic resist disappointment of 100%, the elastic disappointment stress is in this manner 4.7, not really set in stone from the pressure strain bend acquired from material ductile testing on the polyurethane.

Devin et al., (2003) said the re-enactment yields a material disappointment at that specific pressure, showing infiltration through the elastic. This happens at roughly 2.7 seconds. Accordingly, with a vastly inflexible 41 needle with the calculation of the needle in this model, entrance ought to happen roughly 2.7 seconds after starting contact with the elastic, given a consistent speed of 100 mm/min. Albeit the recreation likewise created results for the powers following up on the elastic, these were conflicting with both the anticipated powers from segment 3.1 and those deliberate in infiltration tests. The two sorts of power yield from incorporate contact powers and response powers. In this model, the response powers were just situated along the edges where the limit conditions were applied. The contact powers were

estimated between the characterized contact regions on both the elastic and the needle. These were determined to be just about as high as 108 N, and they were just present on substituting time ventures (with a power of 0 N on the other time steps). This outcome might be because of a mistaken definition in deciding how the powers are determined. Generally, the powers determined by the reproduction are very high and unpredictable; thusly, these outcomes are not utilized in foreseeing the needle infiltration conduct.

3.5 Electrical Testing and Results

When there is a quick stock of d.c power (5vdc) in the entire framework, the miniature regulator (atmega328p) which is the cerebrum of the entire framework conveys a yield signal through it yield pins (#2,3,4 and 5). The yields signal is gotten by the stepper engine driver module (DM1), the driver module gives out a comparing yield signal through it yield terminals to the stepper engines (m1 and m2) associated with it. At the point when the stepper engine is empowered, the engines (m1 and m2) move at the same time at a clockwise heading for 10secs all things considered. Based on the mechanical compartment of the framework, during the principal turn process a fastener is mounted inflexibly to the engine, its fixed that during its pivot the fastener will be in a bad way to a nut and still up in the air time (10secs) the miniature regulator seizes to supply sign to the before referenced pins at the termination of our customized time. As shown in figure 4.16.

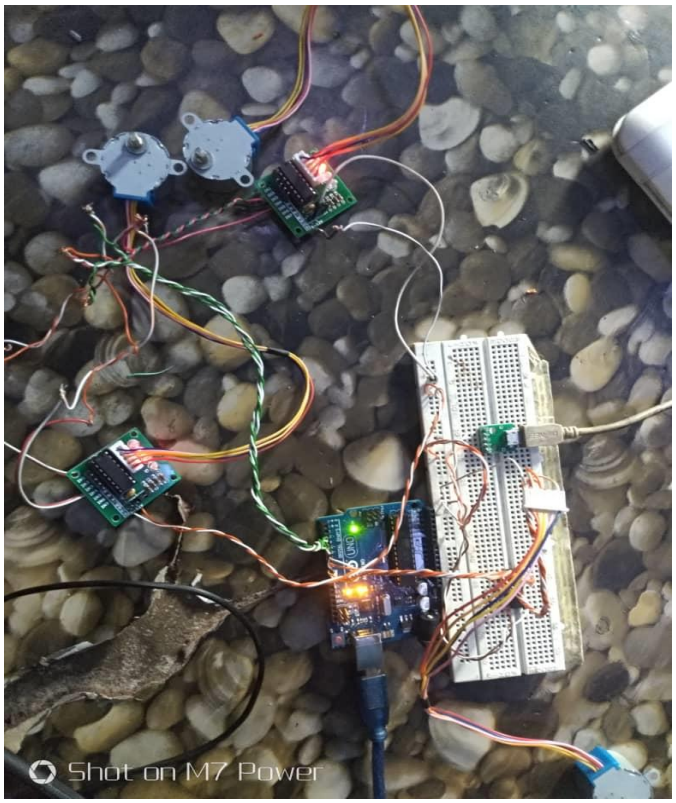

Fig 3.16 Electrical Component Testing

Besides, the miniature regulator gives one more arrangement of yield signal through it yield pin (6,7,8 and 9) to the subsequent stepper engine driver (DM2), which thusly stimulates the stepper engine (m3). The mechanical compartment for this engine is outfitted at controlling the splunger of our needle which should get a necessary tension (power) in other for the liquid to leave the spout.

Fig 3.17 Electrical Component Testing

4.1 Summary of Findings

The aim of this study was to design and model an automated strap-on precision syringe injector. Pursuance to this aim, the project was divided into three major aspects: the CAD aspect, the mechanical aspect and the electrical/automation aspect. The CAD design was the first process in achieving our stated aim, this took care of all parts drawings, dimensions, simulations of the various parts of the device etc. while the mechanical part took care of all model fabrications and constructions of the various designed parts of the device, the electrical aspect took care of all electrical constructions and simulations of the physical parts that where being fabricated.

In compliance with the objectives of the project, for the CAD design SOLID WORKS software was used extensively to design every aspect of the model, also ANSYS software was used to determine the buckling characteristics of the needle in question, and the theoretical buckling load was calculated a determined, all this was done to determine the compatibility of the device

with both the syringe and the needle. Various electrical testing was carried out and various mechanic determination during the fabrication of the device. The following features of the device where achieved; a syringe injector that will be able to make about two to three degree of freedom to enable the user administer drugs in just a simple process, a syringe injector that will allow the user to self-administer injections, especially to the buttocks area of the body, an injection device that will increase injection precision, thereby reducing the number of injection complications.

4.2 Limitation of The Study

These are some of the limitations that was experienced during the cause of carrying out the project.

1. **Design Stage:** There were no much difficulty experienced during the CAD design of the project apart from the fact that during the design stage there where so many modifications and changes as a result of some limitations and access to materials and equipment.
2. **Mechanical Fabrication:** Unavailability of 3D printers where to print some of the mechanical parts of the device, so the use of locally sourced materials where resorted to for the design of those parts, and the issue of getting a multiple start screw that will increase the lead (linear travel).
3. **Electrical Design:** Issue of speed increment was one of the major challenges as the delivery time of the device was too long. Also reprogramming the device to suite, the various modifications made during the project fabrication process.

4.3 Conclusions

In conclusion, at the end of both the design an fabrication of the device model, the device was tested by strapping the device on a dummy baby, then with a press of a button the drug was successfully administer. All aims and objectives where actualized as stated in chapter one of this project.

4.4 Recommendations

Based on the findings of this project work, the following recommendations were made:

1. 3D printers should be made available for students to carry out various design printing to give better design out comes.
2. Better electrical components should be sourced for or customized to replace locally fabricated or sourced material e.g electrical actuators should be used to replace the bold, nut and motor mechanism, which will in-turn give better output and more precision to the device.
3. Further studies should be carried out to improve the quality of the device
4. Further steps should be taken to patent the device which will in-turn proceed the device for further testing which will include human testing of the device.
5.

4.5 Contribution to Knowledge

Findings from this study has contributed to the academia in the following ways.

1. A well modelled self-injecting device was modelled which will solve a lot of problems as stated in chapter one of the project.

2. This device will help in fast drug delivery without the help of a third party.
Ease of administration of drugs using syringes and needle will significantly improve

Author Contributions: The author contributions for " design and modelling of an automated strap-on precision syringe injector device" encompassed conceptualization, drafting, review, supervision, project administration, and funding acquisition, with each author contributing to these aspects to ensure the comprehensive coverage of the topic and the accuracy of the content.
Funding: This research received no external funding.

Institutional Review Board Statement: This study was approved by the Institutional Review Board at University of Ibadan.

Informed Consent Statement: Informed consent was obtained from all subjects involved in the study.

Data Availability Statement: Data is available upon request to the corresponding author subject to IRB restrictions and approval.

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